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CORDAX SHIPPING CHECK LIST

Customer: SCIENTIFIC ATLANTA P.O. No: 59-9601-80 Date: 1/13/81

S.O. No: 26346701 File No: 26346700

Model 803 50080001	(X)	(✓)
Model 805 50080101	( )	( )
Model 807 50080201	( )	( )

Inspector: _____ Title: _____ Date: _____

TO BE SHIPPED WITH EVERY MACHINE MARKED WITH (X)	Insp.	Ship
Isolation Pads (3) & Screws (5)	(X)	(✓)
Instruction Manuals (2)	(X)	(✓)
Foot Switch (All Machines) Except machines with Dec. PDP-11 Comp.	(X)	(✓)
Y-Axis Reading Head (All Machines)	(X)	(✓)
Dust Protection Covers (2-Rolls)	(X)	(✓)
Z-Axis Probe	(X)	(✓)
Z-Axis Probe Shaft	(X)	(✓)

CHECK FOR YELLOW TAGS

(1) On back panel - right side (Caution—Read manual, etc.)	(X)	(✓)
(1) For elevating table, above the switch right side of base (Caution – Keep hands from under the table, etc.)	( )	( )
(1) Under "Y" carriage, close to the front panel Z-Axis tag (Caution—Do not place hands, etc.)	(X)	(✓)
(1) Serial Number Tag - To be mounted on the upper right side of the base, close to the front panel	(X)	(✓)

ACCESSORIES:

Machine Cover	(X)	(✓)
Console Cover	( )	( )
Machine Side Mount (Stand)	(X)	(✓)
Podium Stand	( )	( )

Tables For:

Model 803	(X)	(✓)
Model 805	( )	( )
Model 807	( )	( )
Standard	( )	( )
Standard With Raised Table (Supports)	( )	( )
Elevating-Table ___ Hydraulic (Includes 3 Sets, Riser Tubes)	(X)	(✓)

Console:

3-Axis 3-Display	( )	( )

ACCESSORIES:

PROBES SET NO. 50015420		Insp.	Ship
0 – .450	50007667	(X)	(✓)
.370– .720	50007668	(X)	(✓)
.690–1.040	50007669	(X)	(✓)
1.010–1.360	50007670	(X)	(✓)
1.330–1.680	50007671	(X)	(✓)
1.650–2.000	50007672	(X)	(✓)
1.985–2.335	50007673	(X)	(✓)
2.320–2.670	50007674	(X)	(✓)
2.665–3.005	50007675	(X)	(✓)
Rotating Flat Face	50022164	(X)	(✓)

BALL PROBE KIT NO. 50023214			
.125	50015476	( )	( )
.250	50015477	( )	( )
.375	50015478	( )	( )
.500	50015479	( )	( )
.625	50015480	( )	( )
.750	50015481	( )	( )
.875	50015482	( )	( )
1,000	50015483	( )	( )
Ball Tip Adaptor	50013531	( )	( )
TP2 Probe Ext. Kit	30501196	(X)	(✓)
TP1 Probe Stylus Kit	30501195	(X)	(✓)
Omni Probe Kit	~~30501194~~ 30501811	(X)	(✓)
Chuck Adaptor Probe	50015889	( )	( )
Chuck 0–3/8	50015888	( )	( )
Chuck 1/32 – 1/2	50015887	( )	( )
Fixed R.A. Adaptor	50020743	( )	( )
R.A. Adaptor	50013532	(X)	(✓)
Probe Box	50520219	(X)	(✓)
Auto Center Punch	50007790	( )	( )
Clamp Kit	50080891	(X)	(✓)
Viewing Screen	50080925	( )	( )
Checkout Plate	50015400	( )	( )
Checkout Plate Probe	50015397	( )	( )
1½ DIA. DATUM RETRV. BALL	58000201	(X)	(✓)
SPARE PARTS KIT	50081125	(X)	(✓)
TELETYPE ASR-43		(X)	(✓)
		( )	( )
		( )	( )
		( )	( )
		( )	( )
		( )	( )
		( )	( )
		( )	( )

THE BENDIX CORPORATION

AUTOMATION AND MEASUREMENT DIVISION

INSTRUCTION MANUAL

FOR THE

BENDIX CORDAX®

COORDINATE MEASURING MACHINE

MODELS 803, 805, and 807

JULY 1979

Manual Number 50024496

Bendix reserves the right to make equipment changes and improvements which may not be reflected in this manual.

It is recommended that this document be read in its entirety before any attempt is made to operate or make any adjustment to the equipment.

Although every attempt has been made to present infromation which is both complete and current, variations either in equipment configurations or in equipment application, or both, make it impossible to cover all contingencies in a single document.

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Part I

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PREFACE

The Cordax Coordinate Measuring Machine warranty will be voided by attempting to set up the machine without instructions from The Bendix Corporation, Automation and Measurement Division, Service Department. Call (513) 254-5377 to schedule a service call for installation or write the Service Department at the address given.

For preliminary instructions on uncrating and placement of the machine, refer to Section 4. Initial Installation.

THE BENDIX CORPORATION
Automation and Measurement Division
721 Springfield Street, Post Office Box 1127
Attention: Service Department
Dayton, Ohio 45401

SECTION 1. INTRODUCTION

1-1. GENERAL DESCRIPTION

The Bendix Cordax 800 Series Coordinate Measuring Machines are quality control systems. These machines are available in three models and feature metric design, modular construction, and precision performance. The three models, the 803, 805, and 807, provide a wide choice of measurement capacity and accessible worktable area. See figure 1.

All models are equipped with a measurement data system which can range from a single Preprocessor unit, with simultaneous readout of preprocessed measurement data for all axes to an automatic data processing system with servo-driven automatic probe positioning.

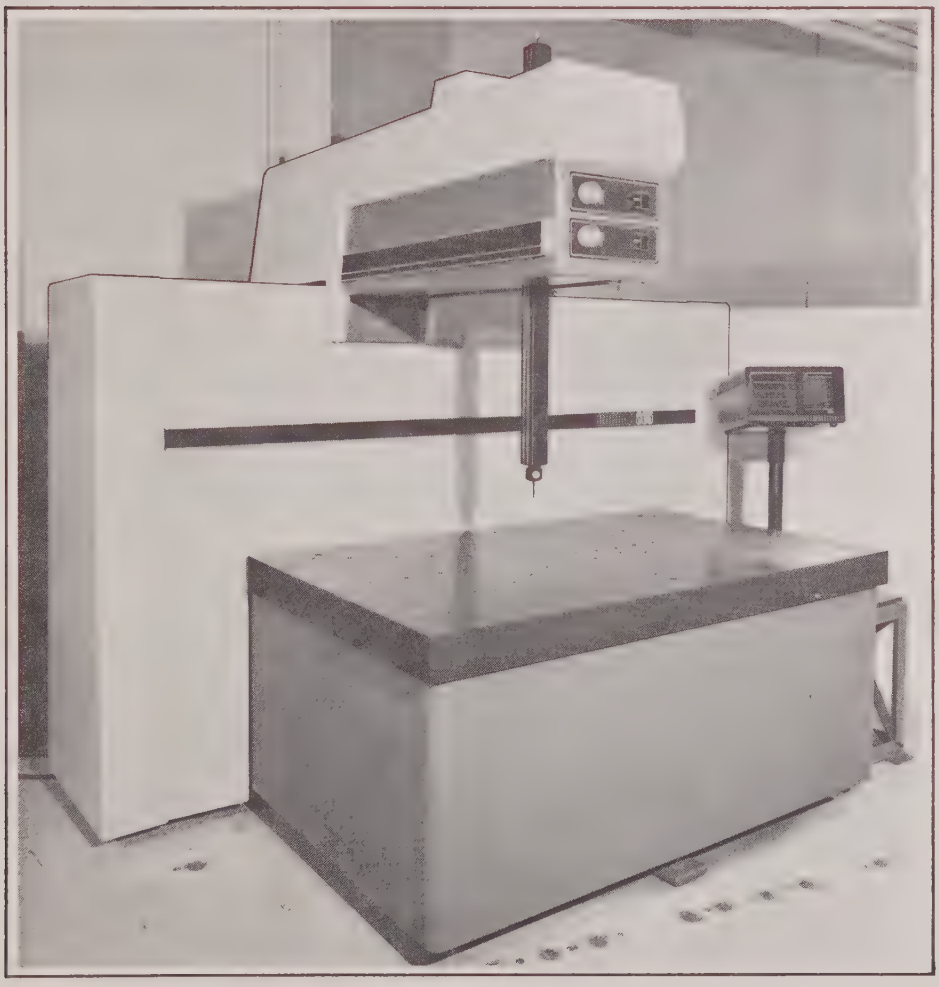


Figure 1. Cordax Coordinate Measuring Machine

Typical applications include final, receiving, and qualifying inspection of machined parts, bearings, plates, and castings of any configuration. Almost any part in any stage of production can be measured precisely. Optional accessories are available for fast scribing, punching, drilling, and optical inspection.

1-2. MACHINE CONSTRUCTION

The Cordax machine base is constructed of welded steel tubular cross sections for maximum rigidity and stability. A three-point suspension system provides additional stability and easy machine leveling. An X-axis steel beam is bolted to the base and designed to accept all loads in both the X- and Y-axis independently of the base. The X-axis bearing ways are an integral part of the X-axis beam. The X-axis moving carriage is mounted to the X-beam and is supported at top and bottom by precision bearings which ride on the X-axis bearing ways.

A box-type trasverse Y-axis beam is bolted to the X-axis carriage. The Y-axis bearing ways are an integral part of the Y-beam. The Y- and Z-axis moving carriage is integrated into a single casting which helps maintain Z-axis squareness and permits longer Y-axis travel. This Y/Z-axis carriage is mounted to the Y-beam at top and bottom by precision bearings which ride on the Y-axis bearing ways. The Y/Z-axis carriage has a one to one geometric ratio with its rear support member to minimize deflection during measurement. The front panel of the Y-axis beam (overarm) contains pneumatic rocker switches for locking the X and Y axes and vernier controls for full range manual fine adjustment of both axes.

The Z-axis probe shaft is supported in the Y/Z-axis carriage by a steel band and precision bearings at top and bottom of the carriage. The bearing ways are machined into the Z-axis shaft. The Z-axis counterbalance is air operated with an air and electric power failsafe system installed. The Z-axis fine adjustment and air lock controls are mounted to the Y/Z carriage. The probe shaft is equipped with a modified No. 3 Morse taper locking and release device for instant probe change.

The fixed steel worktable is mounted to the base and is accessible from three sides. No X- or Y-axis alignment or swivel table is necessary because the electronic circuitry offers two axes alignment as standard. The table top surface is serrated and contains a sunburst bolt pattern. The part and worktable loads are carried directly to the floor by compression loads in the legs. A self-contained hydraulic table lifting mechanism is optional. This feature consists of a one-half horsepower hydraulic unit actuating a three-inch diameter cylinder and three sets of precision-ground matched riser tubes to insert between the base and the table to establish and maintain parallelism of the table top with the X axis.

1-3. MEASURING CONCEPT

The Cordax machine measurement principle is based on the moire fringe concept. This measuring principle incorporates a light-sensitive reading head assembly and a steel grating scale. The reading head unit contains a light source, collimating lens, photocells, and an index grating glass. The steel grating scale and the index grating glass have a precisely calibrated line structure. The index grating line structure, which is the same as that of the steel grating, is superimposed, at a slight angle, on the steel grating scale. The X- and Y-axis grating scales are attached to the stationary member of each axis and the reading heads are attached to the moving members. As the reading head travels along the stationary grating scale, a pattern of dark and light bands is created. This is the moire fringe pattern. This pattern is transformed by the reading head into electrical signals which are proportional to axis movement. These signals are transmitted to the Cordax electronic system where they are processed. A simplified diagram of measurement data acquisition is shown in figure 2.

The measuring principle for the Z-axis is the same except the reading head is attached to the stationary member of the axis and the grating scale is attached to the movable probe shaft.

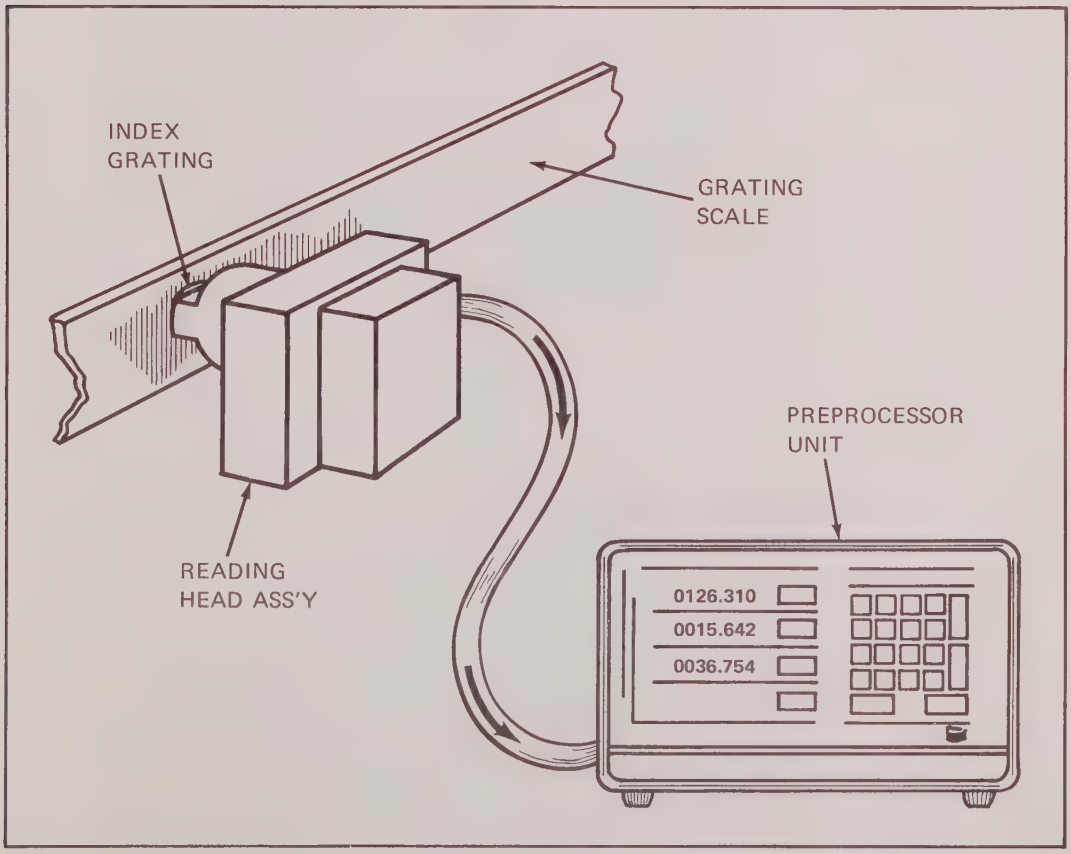


Figure 2. Cordax Measurement Data Flow

1-4. MACHINE CONTROLS

The Cordax 800 Series Measuring Machine controls are shown in Figure 3.

a. Pneumatic Lock Switches: Actuates an air cylinder to prevent manual movement of the axis. One switch for each axis.

b. Vernier Controls: Allows fine adjustment of the axis within the full measuring range during lock condition. One control for each axis.

c. Probe Release: A mechanism employed in the Z axis for releasing the probe or attachment.

d. Elevating Table Switches: The UP pushbutton actuates the hydraulic motor for raising the worktable. The DOWN pushbutton actuates a hydraulic release valve for lowering the worktable. (These switches are present only with the optional elevating table.)

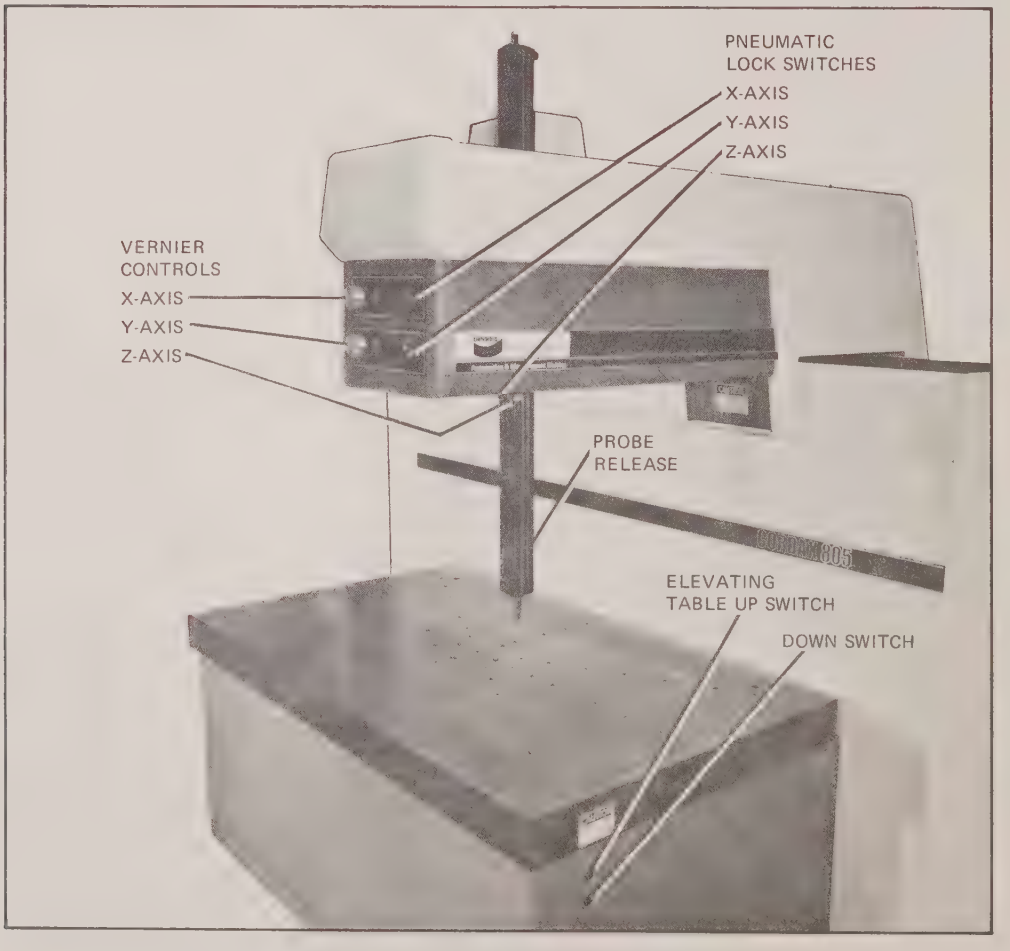


Figure 3. Machine Controls

SECTION 2. ACCESSORIES

2-1. TOOLING AND ATTACHMENTS

A wide variety of standard and special tooling and various attachments are available for the Cordax measuring machines (see figures 4, 5, and 6). All tooling and attachments are inserted into the bottom of the Z-axis probe shaft. The tooling automatically locks into place when pressed upward and is quickly changed by using the releasing mechanism. Some special tooling and Z-axis attachments are bolted to the probe shaft for added support. The Bendix Corporation, Automation and Measurement Division will design and fabricate specific tooling for the customer. A complete listing of accessory part with the eight-digit Bendix stock number is given in section 8. A list of some standard and special tooling and Z-axis attachments is as follows:

a. Taper probes.
b. Ball tip probes.
c. Right angle probes.
d. Albrecht chuck probes.
e. Disk probes.
f. Scriber probes.
g. Adaptor probes.
h. Rotating flat-faced probes.
i. Omnidirectional touch probes.
j. Automatic center punch attachment.
k. Centering Projector attachment.
l. Microscope attachment.

2-2. OPTIONAL EQUIPMENT

There are many options and optional equipment available for use with the Cordax machines. Some of these options are as follows:

a. Hydraulic elevating table.
b. Raised fixed table.
c. Rotary air transport table.
d. Part clamp kit.
e. Checkout plate.
f. Probes and attachments.
g. Electrical Z-axis counterbalance.
h. Electrical fine feed adjustment.
i. Various length Y-axis options.
j. Various length Z-axis options.
k. DCC drive option.
l. Measurement preprocessor.
m. Measurement preprocessor mounting podium.

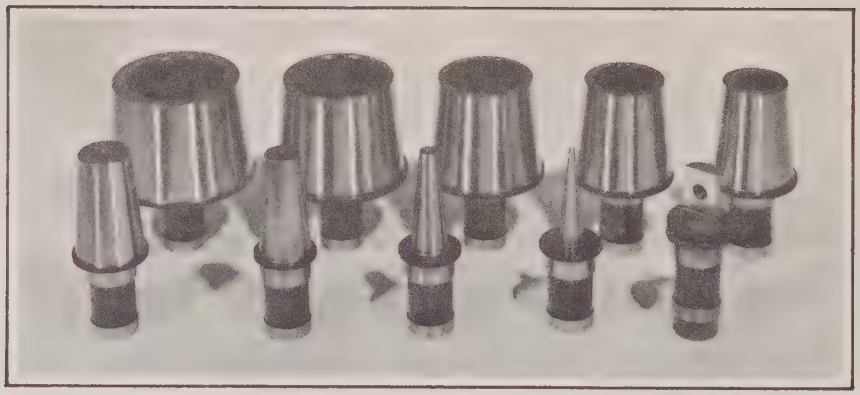


Figure 4. Taper Probe Set

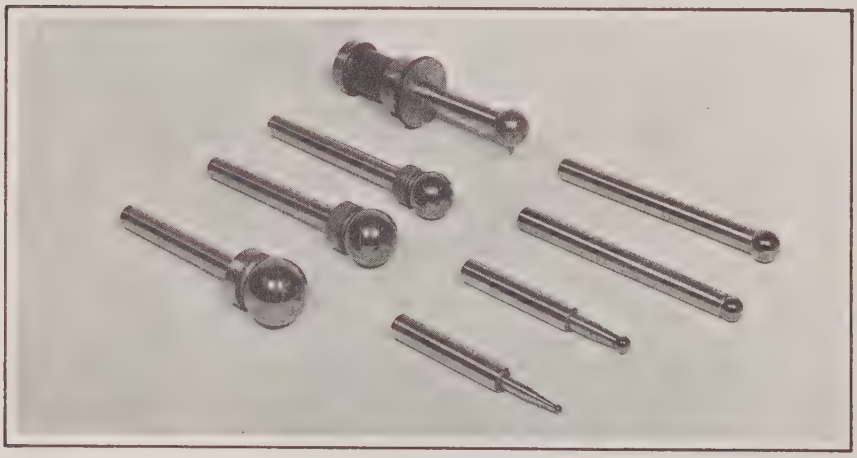


Figure 5. Ball Tip Probe Set

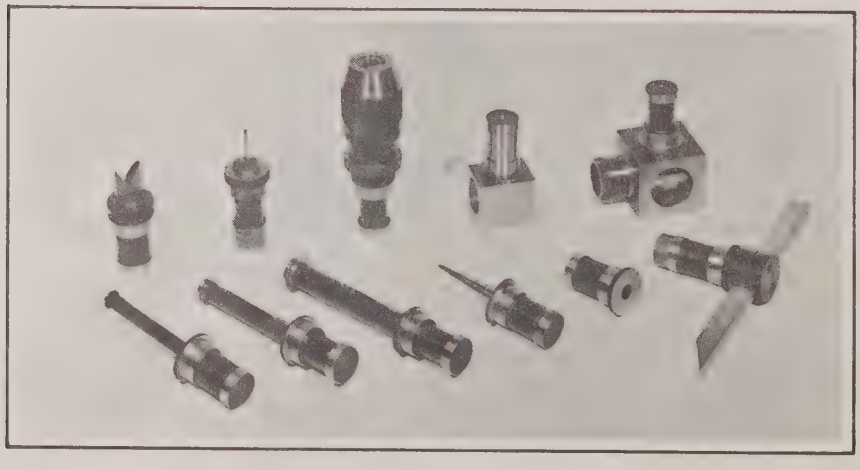


Figure 6. Special Probes

SECTION 3. MACHINE SPECIFICATIONS

Table 1 lists the machine specifications for the Cordax Coordinate Measuring Machines, models 803, 805, and 807. Cordax electronic system specifications are given elsewhere in this manual.

Table 1. Specifications for Cordax 800 Series Coordinate Measuring Machines

Detail	Model 803	Model 805	Model 807
Measuring Range			
X axis	1000 mm (39.4 in.)	1500 mm (59.1 in.)	2000 mm (78.7 in.)
Y axis	700 mm 27.6 in.)* 800 mm (31.5 in.) 900 mm (35.4 in.) 1000 mm (39.4 in.)	800 mm (31.5 in.)* 900 mm (35.4 in.) 1000 mm (39.4 in.)	900 mm (35.4 in.)* 1000 mm (39.4 in.)
Z axis	400 mm (15.8 in.)* 700 mm (27.6 in.) 1000 mm (39.4 in.)	400 mm (15.8 in.)* 700 mm (27.6 in.) 1000 mm (39.4 in.)	400 mm (15.8 in.)* 700 mm (27.6 in.) 1000 mm (39.4 in.)
Work Height Capacity	50 mm (2 in.) greater than Z-axis range*	50 mm (2 in.) greater than Z-axis range*	50 mm (2 in.) greater than Z-axis range*
Work Load and Elevating Capacity	540 kg (1200 lb)	900 kg (2000 lb)	900 kg (2000 lb)
Worktable Area	1080 mm x 825 mm (42.5 in. x 32.5 in.)	1580 mm x 925 mm (62.2 in. x 36.4 in.)	2080 mm x 1025 mm (81.9 in. x 40.4 in.)
Elevating Table Travel	300 mm (11.8 in.)	300 mm (11.8 in.)	300 mm (11.8 in.)
Elevating Table Supply Voltage	115 VAC 50/60 Hz	115 VAC 50/60 Hz	115 VAC 50/60 Hz
Z-axis Gaging Force	225 g (8 oz)**	225 g (8 oz)**	225 g (8 oz)**
Weight (approx)	1980 kg (440 lb)	2770 kg (6100 lb)	4220 kg (9300 lb)
Overall Dimensions	Refer to Figure 8	Refer to Figure 8	Refer to Figure 8

* Denotes standard size.
** Denote adjustable.

SECTION 4. INITIAL INSTALLATION

4-1. ENVIRONMENTAL CONSIDERATIONS

The proper installation of the Cordax Measuring Machine is a major factor in achieving optimum performance. The procedures usually associated with machine tool installation are normally adequate; however, the following points should be considered before the machine is installed:

a. Environment: The Cordax Measuring Machine is designed for shop environment usage. Normal stable temperature has no significant effect. However, cleanliness and temperature variations are major factors which can affect machine performance. Install the machine in a reasonably clean area which is free from drafts. It is recommended that temperature variations not exceed a 3° C (5° F) change per four-hour period and not exceed a 6° C (11° F) maximum variation from initial setup temperature.

b. Vibration: A major concern of any inspection equipment is vibration. Locate the machine away from severe vibration sources such as air compressors, punch presses, large mills, railroads, forklifts, etc. Isolation pads made of neoprene fiberglass composition are shipped with each machine to aid in vibration dampening.

c. Foundation: Do not locate the Cordax machine on wood structured floors which can sag or vibrate, or directly on surfaces which tend to "cold flow" or settle under load (for example, tile, linoleum, wood blocks). Ground-supported concrete is recommended. In cases where tile or wood blocks are laid on concrete, remove the tile or blocks immediately under the leveling screws so that the isolation pads rest directly on the concrete.

d. AC Power Source: Noise rejection was a primary consideration in the design of the electronic circuitry. However, the electronic equipment will function best where noise is minimized. Avoid AC power lines supplying heavy induction equipment, such as welders, large motors, and induction furnaces, which cause large line fluctuations and/or generate electronic noises. An isolation transformer should be used for the electronic system when a fluctuating or noisy power line cannot be avoided. Do not connect the optional elevating table to the same power source supplying the electronic system.

e. Air Supply: A nominally clean and dry air supply of 542 kPa (80 psig) and 0.084 cubic meter per minute (3 scfm) minimum is required. If the air supply is wet and dirty, an additional filtering system is required.

4-2. UNCRATING

The Cordax Measuring Machine is shipped prealigned and factory adjusted. It is capable of precise measurements after installation and initial check-out by an authorized Bendix Service Representative. Uncrate the machine, using care to avoid any damage from mishandling, and remove it from the skid, using the following instructions:

IMPORTANT: If the machine or equipment appears to have been damaged during shipment, call the transportation company immediately and file a claim for damages. The transportation company is responsible for the shipment after it leaves the Bendix Plant.

a. Remove all crating, paper packing, and loose boxes. Only unpack the shipping carton labeled leveling screws or instruction manual. Do not remove the Y-axis overarm brace which is bolted to the table.

b. Elevate the machine and skid using an overhead crane that is adequate for the task. See figure 7 for the four lifting points. Refer to table 2 for the different machine weights.

c. Install 12-inch blocks under the two main skid beams and lower the skid and machine onto these blocks.

d. Remove the three shipping bolts that secure the skid to the machine. They are bolted at the three machine leveling points, see figure 7.

e. Elevate the machine and remove the shipping skid. While the machine is supported, assemble the three leveling screws and the two stabilizing screws. Then lower the machine to the floor.

f. Approach the machine from the rear with a fortlift and position the forks under the machine lifting supports. The rear cover has an area cut out for the forks to enter. The inside front of the machine base has a lifting channel welded to it for front-end lifting support, see figure 7. Refer to table 2 for the required fork lengths.

CAUTION: Ensure that the forklift forks will avoid the elevating table lifting cylinder, if present.

g. Set the machine into position with the three machine leveling screws resting on the isolation pads, see figure 7. If the machine is equipped with an elevating table, place the neoprene pad between the table lifting cylinder and the floor. Figure 8 shows a floor plan for the Cordax machine.

NOTE: To lift the machine from the front, insert an 8-inch block between the forklift forks and the rear lifting channel. The machine can also be set on rollers or casters to move it into place. Use hydraulic jacks or similar devices to remove the rollers from under the machine. Set the jacks near the three leveling screws when lifting the machine, see figure 7. When placing the machine against a wall leave a minimum of 0.6 meter (2 ft.) between the machine and wall for servicing purpose.

Table 2. Forklift Loading Specifications

Detail	Model 803	Model 805	Model 807
Weight approx. with skid	2115 kg (4700 lb)	2950 kg (6500 lb)	4225 kg (9700 lb)
Fork Length	1425 mm (56 in.)	1525 mm (60 in.)	1625 mm (64 in.)

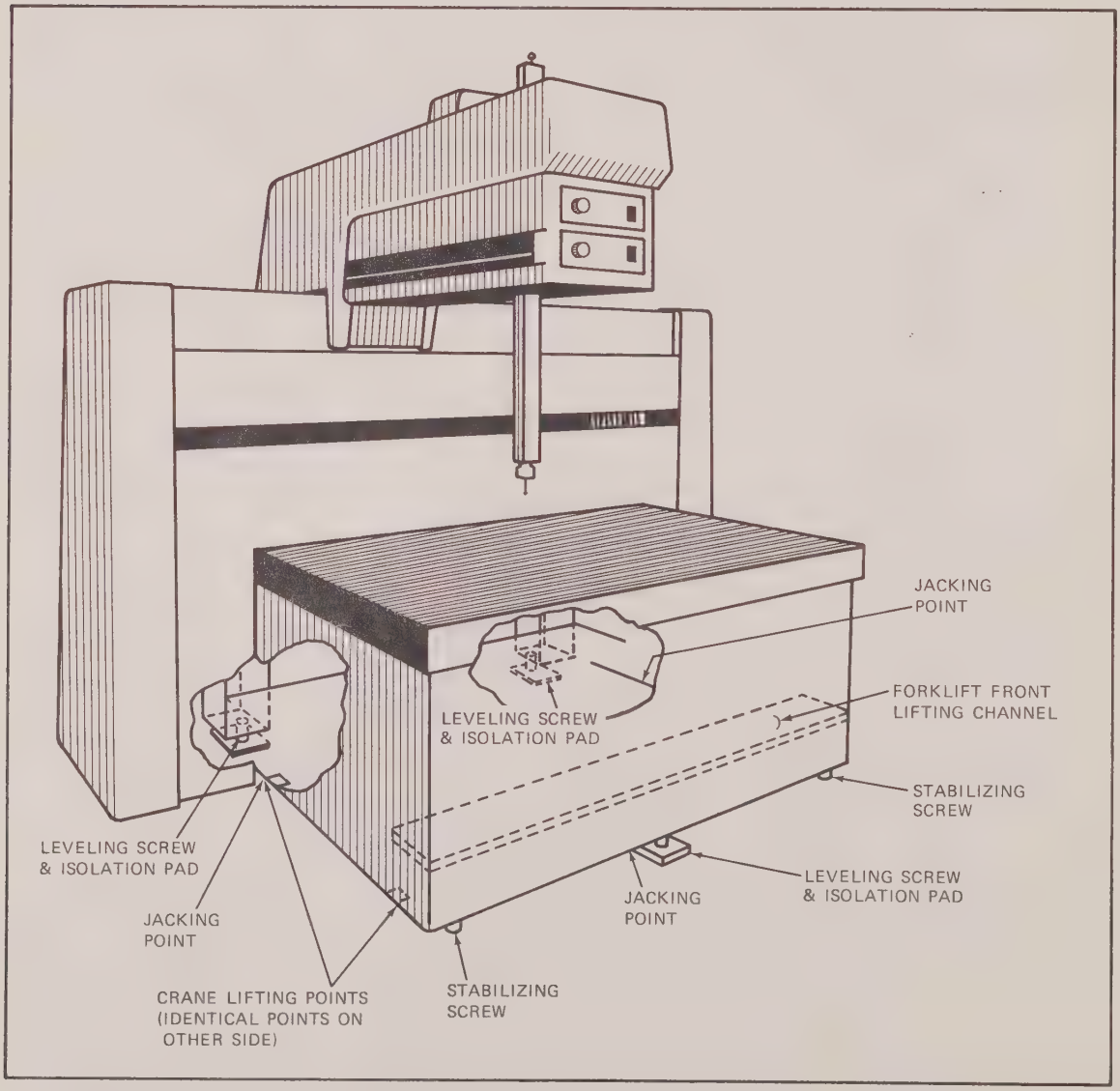
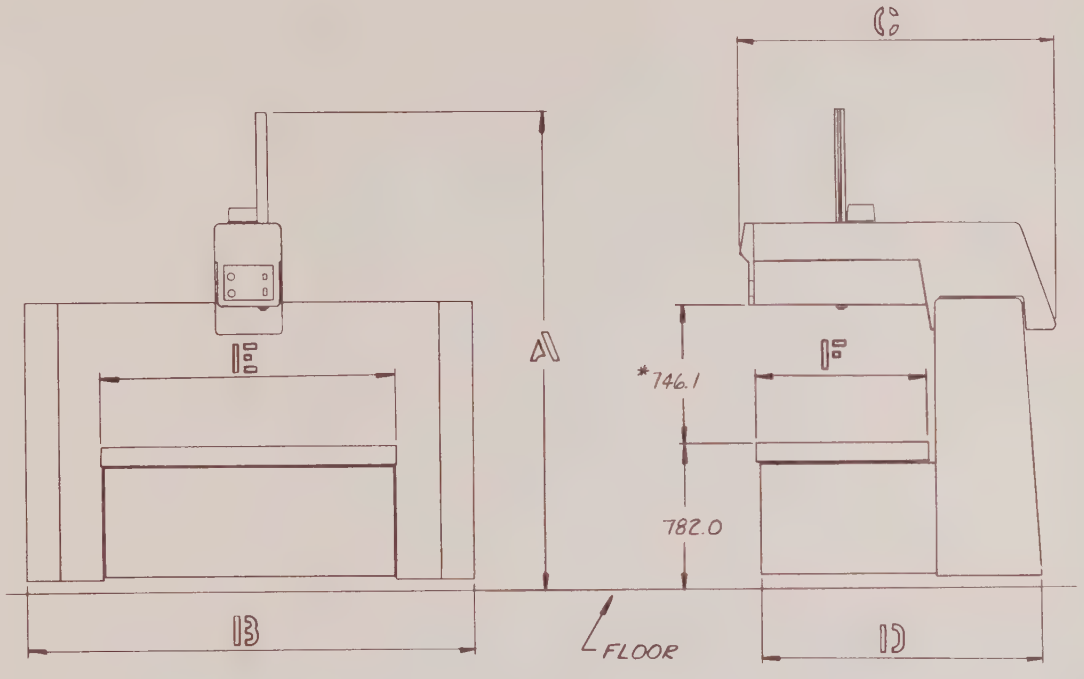


Figure 7. Machine Leveling and Lifting Points



*FOR 1000 MM Z
ADD 305.0

A	1000 'Z'	700 'Z'	400 'Z'
	3206.2	2601.2	2301.2

B	MODEL 807	MODEL 805	MODEL 803
	2888.2	2388.2	1888.2

C	1000 'Y'	900 'Y'	800 'Y'	700 'Y'
	1900.2	1800.2	1700.2	1600.2

D	MODEL 807	MODEL 805	MODEL 803
	1622.7	1522.7	1418.3

— NOTE: FOR 1000 MM 'Z' ADD 21.3

E	MODEL 807	MODEL 805	MODEL 803
	2080.0	1580.0	1080.0

F	MODEL 807	MODEL 805	MODEL 803
	1025.0	925.0	825.0

Figure 8. Machine Floor Plan

SECTION 5. SETUP AND OPERATION

5-1. GENERAL PRECAUTIONS

Before initial operation, ensure that the Cordax machine has been checked and set up by an authorized Bendix Service Representative. The operator must become familiar with all the controls and tooling and their uses to increase efficiency in using the machine to measure the various parts which may be encountered. Keeping the machine, work area, and parts to be inspected clean and free from dust, chips, and oil will help considerably in the machine performance. The normal industrial safety rules and precautions should be followed when operating the Cordax machine.

WARNING: When using the optional elevating table, grip the riser tubes as shown in Figure 9 when placing the tubes under the table. Do not place fingers over the edge of the tube and do not lower the table until the riser tubes are in place. Never leave the table unsupported while loading or unloading parts or at any other time. Never place hands or fingers under an unsupported table except for placement of the riser tubes.

Figure 9. Riser Tube Placement

5-2. MACHINE OPERATION

WARNING: Always lock the Z-axis probe shaft by setting the Z-axis lock toggle switch to the lock position when the machine is turned off or left unattended.

In operation, the part or component to be measured is mounted securely but without tension to the machine worktable by using appropriate mounting bolts, clamps, and blocks. Place the surface to be measured on the table below the Y-overarm, preferably at a height from 25.4 to 254 millimeters (1 to 10 inches). No mechanical X- and Y-axis alignment is necessary; implementing the part alignment function in the measurement preprocessor unit will mathematically align the part with the machine. If using the optional elevating table, press and hold the elevating table UP pushbutton to raise the table to the desired height. Insert a matched set of riser tubes into place observing the WARNING statement given in section 5-1. Lower the table onto the tubes by pressing the DOWN pushbutton until contact is made. Check to see that the riser tubes are secure. Figure 10 illustrates the Cordax machine axes movement.

CAUTION: Do not place hand between the probe and table when removing the probe.

The proper probe is selected to accommodate the conditions of the part to be measured. Insert the probe into the Z-axis probe shaft and push upward with a slight twist to lock the probe in place. Remove the probe by firmly grasping the probe with one hand while raising and releasing the Probe Release Lever with the other hand. This will cause the probe to drop out of the probe shaft.

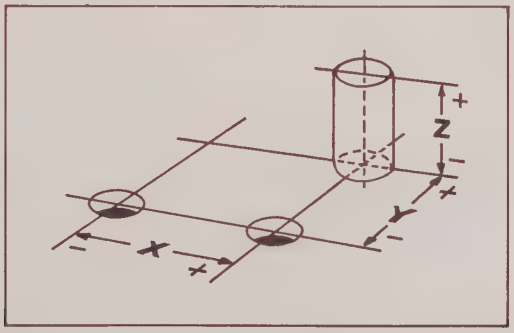


Figure 10. Axes Movement

With a suitable probe in place, move the probe to the part reference position and reset the digital display to establish a zero reference. A zero reference can be established at any point within the measuring range. The probe is then moved progressively to the various points of inspection with all axes coordinate dimensions at each check point being displayed simultaneously on the digital readout. The electronic system provides instant readout response to probe

movement. An example of this four-quadrant readout principle is given in Figure 11. For establishing exact points for purposes of line scribing and center punching, engage the locks for each axis and turn the fine adjustment controls to set the final dimension. For readings of hole positions, insert a tapered probe into the hole. For complete details of measurement operations, refer to the electronic system description.

*When using a heavy probe or attachment such as the optical viewing screen, the Z-axis gaging force may need adjusting. Refer to section 6-4. Z-axis Counterbalance Adjustment.

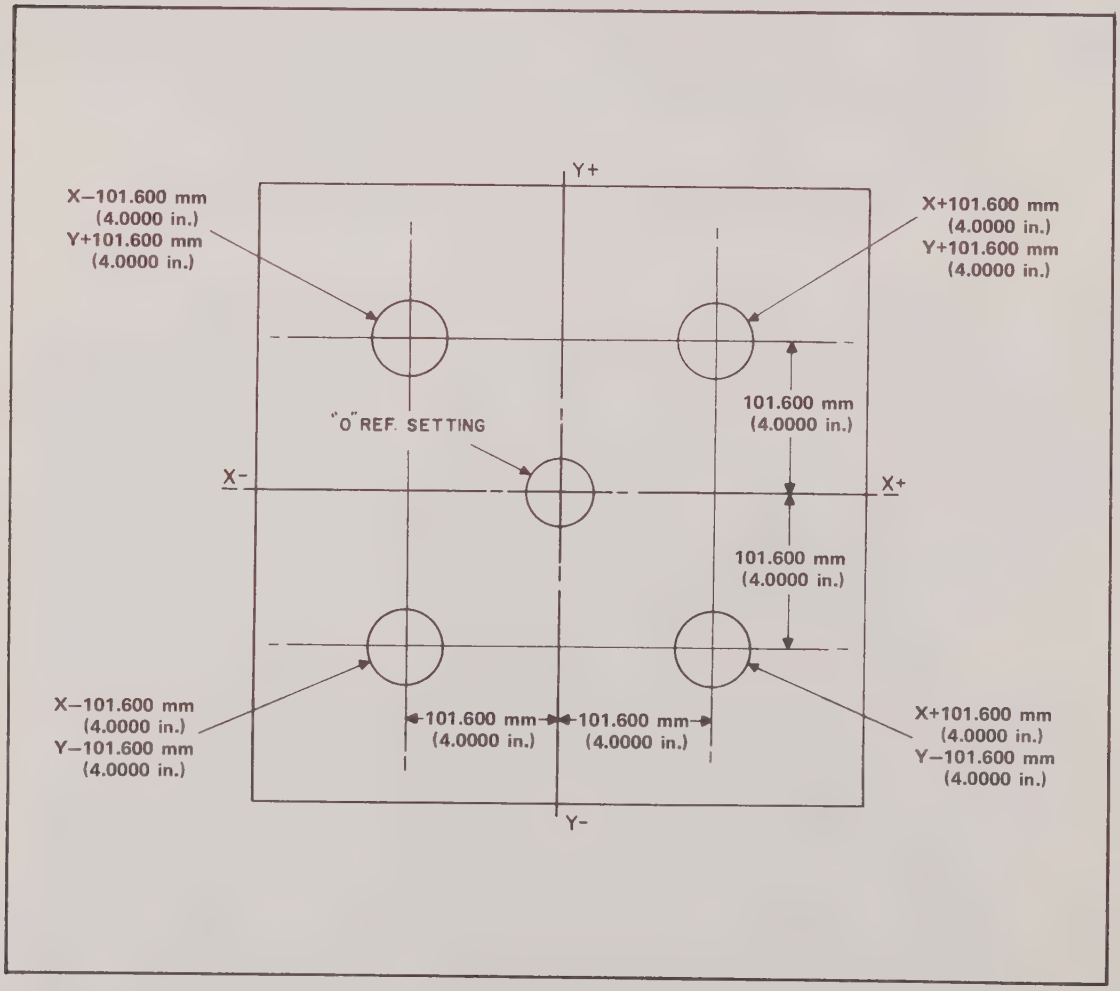


Figure 11. Four-Quadrant Readout Principal

SECTION 6. MAINTENANCE AND ADJUSTMENTS

6-1. CLEANING AND LUBRICATION

Procedures for cleaning and lubricating the Cordax Coordinate Measuring Machine are contained in this section. Refer to the electronic system portion of this manual for pertinent maintenance and adjustment information.

a. Cleaning

The Cordax machine must be kept clean and free from dirt, dust, and oil at all times to obtain best results. If oil gets on the bearing ways they will collect dirt and this grit build-up will eventually affect the machine performance. If at any time a sticky or stiff movement is noticed on any axis, clean the bearings and bearing ways as described in the following steps:

(1) Remove the machine covers.

(2) Clean the bearings and bearing ways using a clean dry shop rag or equivalent. If needed, a cleaning solvent that does not leave a residue can be used.

NOTE: The surfaces of the bearings, bearing ways, and the table should be cleaned at regular intervals, depending on the machine environment. If the machine is out of use for an extended period, coat the table with a rust perventive solution and cover the machine.

b. Lubrication

If the optional elevating table is present, lubricate the elevating table lifting cylinder (see Figure 12) every six months, using a general purpose lubricant.

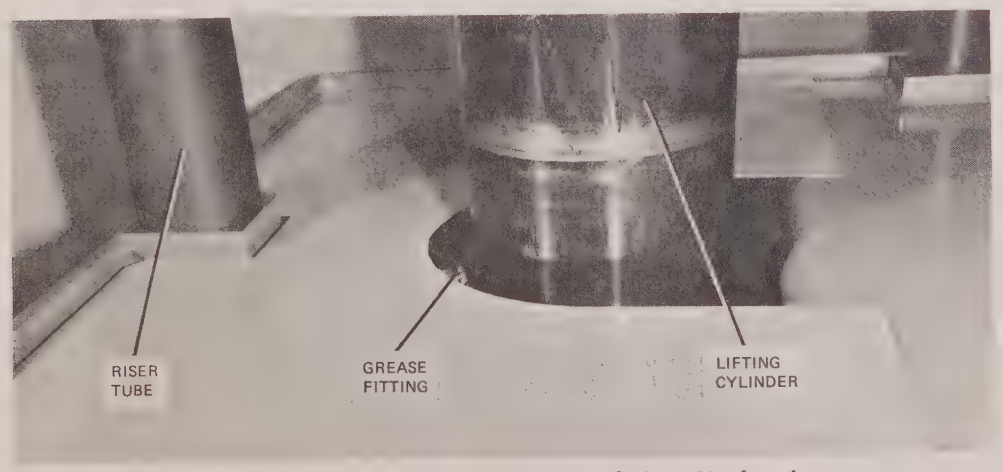


Figure 12. Elevating Table Lifting Mechanism

6-2. MOVING AND LEVELING

a. Moving

Contact the Bendix Automation and Measurement Division Service Department (513) 254-5377 when a Cordax machine is to be relocated. Extensive damage will occur if the inspection machine is not properly packed for moving.

b. Leveling

After initial setup, the machine should remain level; however, it is recommended that the machine be checked annually.

(1) Position a precision machine level on the table top in the Y-axis direction.

(2) Loosen the stabilizing and leveling screw lock nuts and back off the two stabilizing screws.

(3) Adjust the front leveling screw to level the machine in the Y-direction.

(4) Position the level on the table top in the X-axis direction and adjust the two rear leveling screws to level the machine in this direction. Level the Cordax machine to within ±0.003 in./ft. Tighten locknuts.

(5) Turn the two stabilizing screws until they just make contact with the floor, then back them off one-half turn.

NOTE: The machine weight is supported by the three leveling screws. The stabilizing screws should not have any weight on them.

6-3. AIR FILTER/REGULATOR UNIT

The combination air filter/regulator unit, see figure 13, is used to provide a clean, dry, and regulated air supply to the Cordax machine valves and cylinders. The filter/regulator unit includes an anti-surge valve and a factory-set flow control for the Z-axis counterbalance system, and an additional regulator and pressure gage for the air curtains. It also has an automatic drain feature which extracts and expels foreign particles from the incoming air supply; however, the air supplied to the unit must be reasonably clean and dry. If the air supply is dirty or wet use an additional filter and dryer unit.

a. Air Supply Control

To provide a gradual increase in the air flow to the machine, use the regulator pressure adjustment knob, see figure 13, located on the air filter/regulator unit at the rear of the machine or use an auxiliary screw-type valve on the incoming air line to turn the air supply on and off.

CAUTION: Do not use a lever-type on/off control valve which may cause surges to the Z-axis counterbalance system.

b. Adjusting the Air Pressure

(1) Turn on the air supply and turn the regulator pressure adjustment knob clockwise (CW) until the main pressure gage indicates 552 kPa (80 psig). If an auxiliary on/off control is used, ensure that the pressure gage reading is 552 kPa (80 psig). An adjustment of the regulator pressure adjustment knob may be necessary to obtain the proper reading.

(2) Adjust the air curtain regulator to set the curtain pressure gage, see figure 13, to approximately 104 kPa (15 psig).

(3) Instructions for adjusting the Z-axis counterbalance are given in section 6-4. Do not attempt to adjust the flow control on the air filter/regulator unit.

c. Cleaning the Filter Element

(1) Shut off the inlet air to the filter/regulator unit and reduce the pressure in the air lines to zero.

(2) Unscrew and remove the filter bowl which contains the automatic drain feature. Now unscrew and remove the baffle, the sintered bronze filter element and the gasket, if used.

(3) Clean the filter element using warm water and soap. Blow clean filtered air through the filter element in the direction opposite that of normal air flow to dislodge surface contaminants.

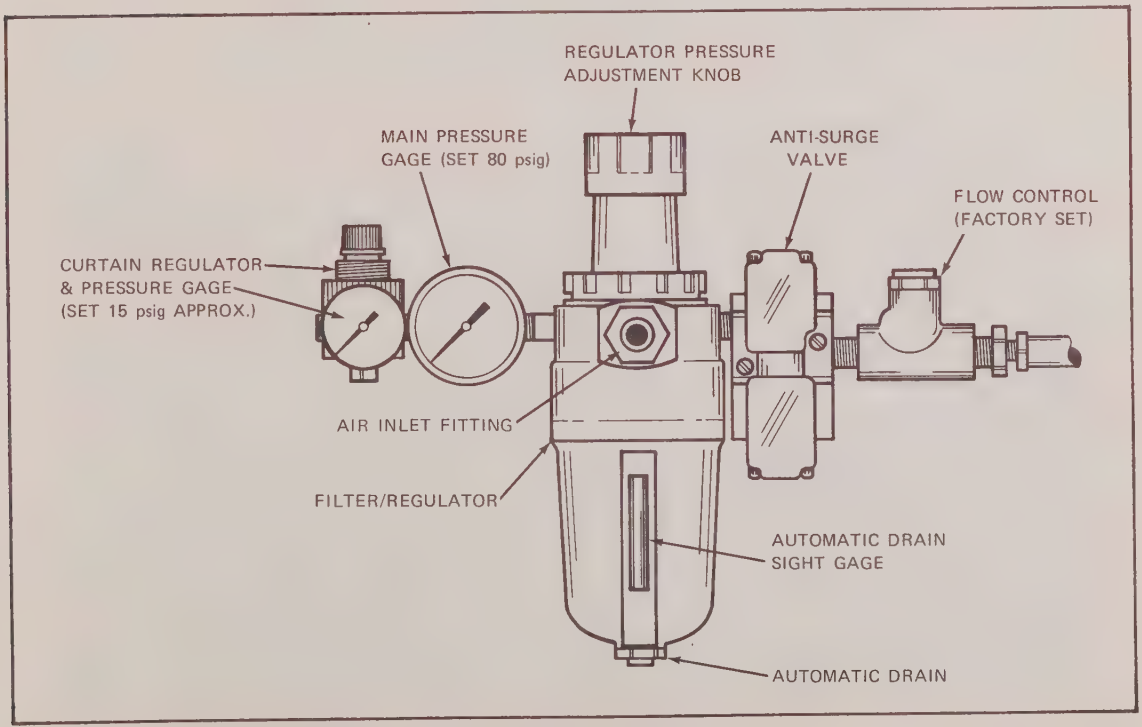


Figure 13. Filter/Regulator Unit

Dry the filter element and blow out the internal passages in the body using clean, dry compressed air.

(4) Apply a wipe coat of Dow-Corning 44M grease (or equivalent) to the gasket and reassemble the filter element. Tighten the baffle hand snug.

(5) Apply a light coating of antiseize compound (Armite Laboratories Led-Plate No. 250 or equivalent) to the threads on the filter bowl and reassemble to body.

IMPORTANT: If the automatic drain does not function properly a liquid level will be observed in the automatic drain sight glass, see figure 13. The drain mechanism is not repairable and must be replaced. Refer servicing to your local Norgren supplier or contact the following:

C. A. Norgren Co.
Litteton, Colorado 80120
Area Code (303) 794-2611

6-4. Z-AXIS COUNTERBALANCE ADJUSTMENT

The Z-axis counterbalance is factory set for a gaging force of 225 g (8 oz). This is the weight of the standard hard probe. When using a Z-axis probe or attachment that weighs 2.25 kg (5 lb.) or more, an adjustment is necessary.

a. To increase the counterbalance air pressure, turn the air counterbalance regulator (see Figure 14) clockwise one-half revolution.

b. To decrease the counterbalance air pressure, turn the air counterbalance regulator counterclockwise one-half revolution.

NOTE: The omnidirectional probe weighs less than a standard hard probe and an adjustment should not be required.

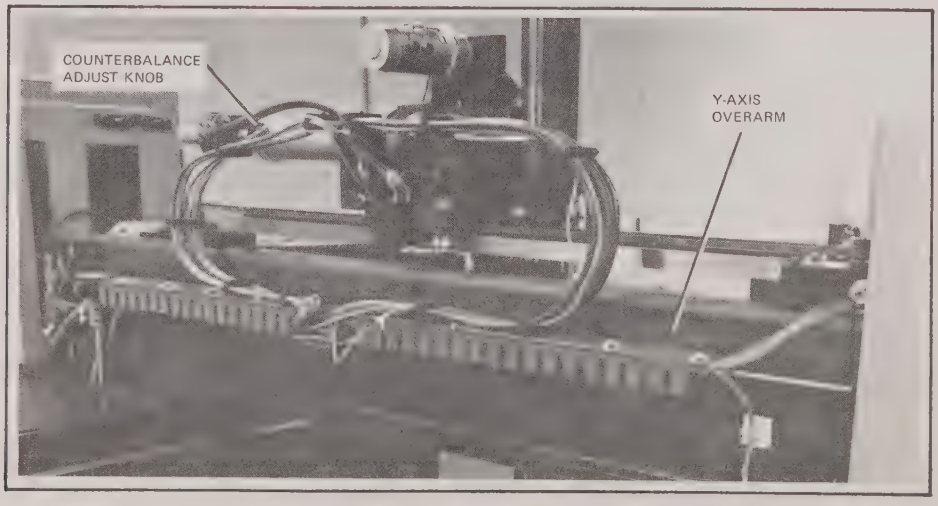


Figure 14. Z-axis Counterbalance Adjustment

6-5. ELECTRICAL Z-AXIS COUNTERBALANCE

The electrical Z-axis counterbalance, an optional feature, provides a means of compensating for the weight of the probe and allows the operator to adjust the Z-axis gaging force. The proper gaging force is determined by the structure and material of the part being measured, as well as, the weight of the probe. The recommended force for most applications is 0.22 kg. With the counterbalance lever (see figure 15), the counterbalance can be adjusted from 0.22 kg (0.5 lb) downward force to 2 kg (4.4 lb) upward force. For Cordax machines without this option, the Z-axis can be adjusted mechanically as described in section 6-4. When using the electrical Z-axis counterbalance for probe compensation and gaging force adjustment, proceed in accordance with the following steps:

a. Set the Z-axis lock to the ON position and insert the probe in the probe shaft.

b. Hold the probe shaft securely in one hand and set the Z-axis lock to the OFF position.

c. With the other hand, hold the gage force lever to the right to increase the downward force or to the left to decrease the downward force. When the probe shaft seems to be balanced, momentarily release it; it should remain in place. If not, continue the adjustment while holding the probe shaft.

d. When the probe shaft is balanced, place a force gage (not included) under the probe shaft and move the lever to the right until the proper gaging force is indicated on the force gage (usually 0.22 kg).

Figure 15. Electrical Z-Axis Counterbalance

SECTION 7. SERVICE AND ACCESSORY PARTS LIST

7-1. WARRANTY STATEMENT

The Bendix Cordax Coordinate Measuring Machine is a precision inspection machine with a highly advanced electronic system. The calibration of the machine is quite complex and requires special electronic test equipment. For this reason, repairs are made by Bendix Field Service Representatives who are skilled electronic technicians experienced in the area of precision measurement technology. Repairs by other than authorized Bendix personnel within the warranty period will automatically void the Bendix warranty. The Cordax Machine should be checked for alignment periodically by an authorized Bendix Service Representative.

7-2. ACCESSORY PARTS LIST

When ordering parts, be sure to specify the eight-digit Bendix stock number and the word description as stated in the parts list. Address spare parts orders to the following address or call the Service Department at (513) 254-5377 for repair service.

The Bendix Corporation
Automation and Measurement Division
721 Springfield Street, Post Office Box 1127
Attn: Order Service Department
Dayton, Ohio 45401

Description	Bendix Stock No.
Probe Storage Box	50520219
Right Angle Adaptor	50013532
90° Right Angle Adaptor	50020743
Chuck Adaptor	50015889
Albrecht Chuck 0 - 3/8	50015888
Albrecht Chuck 1/32 - 1/2	50015887
Omnidirectional Probe Kit	30501194
Rotating Knife Edge Probe	50024311
Carbide Tip Scriber Probe	50009281
Rotating Right Angle Scriber	50014988
Disk Probe 12.70 mm (0.500) Dia.	50023020
Disk Probe 19.05 mm (0.750) Dia.	50023021
Disk Probe 25.40 mm (1.000) Dia.	50023022
Rotating Vee Probe	50023023
Automatic Punch Attachment	50007790
Centering Projector (Metric)	50080925
Single Eyepiece Microscope	50012432
Clamp Kit (Metric)	50080891
Rotary Air Transport Table (Metric)	50080933
34-Ball Checkout Plate	50015400
3-Ball Checkout Plate	50023024

ACCESSORY PARTS LIST (continued)

Description	Probe Diameter MIN.	MAX.	Bendix Stock No.
Taper Probe Set (includes the following)			50015420
Taper Probe	0 0	11.43 mm (0.450 in.)	50007667
Taper Probe	9.40 mm (0.370 in.)	18.29 mm (0.720 in.)	50007668
Taper Probe	17.53 mm (0.690 in.)	26.42 mm (1.040 in.)	50007669
Taper Probe	25.65 mm (1.010 in.)	34.54 (1.360 in.)	50007670
Taper Probe	33.78 mm (1.330 in.)	42.67 mm (1.680 in.)	50007671
Taper Probe	41.91 mm (1.650 in.)	50.80 mm (2.000 in.)	50007672
Taper Probe	50.52 mm (1.985 in.)	59.31 mm (2.335 in.)	50007673
Taper Probe	58.93 mm (2.320 in.)	67.82 mm (2.670 in.)	50007674
Taper Probe	67.44 mm (2.655 in.)	76.33 mm (3.005 in.)	50007675
Rotating Flat Faced Probe	N/A		50022164

Description	Ball Diameter	Bendix Stock No.
Ball Tip Probe Set (includes the following)		50023214
Adaptor Probe 9.525 mm (0.3750 in.) I.D.		50015476
Ball Tip	3.18 mm (0.125 in.)	50015476
Ball Tip	6.35 mm (0.250 in.)	50015477
Ball Tip	9.53 mm (0.375 in.)	50015478
Ball Tip	12.70 mm (0.500 in.)	50015479
Ball Tip	15.88 mm (0.625 in.)	50015480
Ball Tip	19.05 mm (0.750 in.)	50015481
Ball Tip	22.23 mm (0.875 in.)	50015482
Ball Tip	25.40 mm (1.000 in.)	50015483

Bendix Automation & Measurement Division

DOCUMENT CHANGE NOTICE

INSTRUCTION MANUAL FOR THE CORDAX® MEASUREMENT PRE-PROCESSOR™
MODELS MPP, MPP-1 AND MPP-2

Manual No. 50024273 November 1979

Page 4, 2nd paragraph, lines 4 and 5

Change sentence to: The left side of the X-axis is negative and the right side is positive.

Page 19

Insert the following WARNING at the top of the page immediately below the title, SECTION 5. MPP START-UP AND AN EXERCISE FOR MPP OPERATORS

WARNING

For Cordax 800 Series Coordinate Measuring Machine Users
Always lock the Z-axis probe shaft by setting the Z-axis lock toggle switch to the lock position when the machine is turned off or left unattended.

Page 86, paragraph b., line 4

Change line to: of the chassis) until the DC voltage reads 3.5 volts.

DCN 1, August 27, 1980

THE BENDIX CORPORATION

AUTOMATION AND MEASUREMENT DIVISION

INSTRUCTION MANUAL

FOR THE

CORDAX® MEASUREMENT PRE-PROCESSOR™

MODELS MPP, MPP-1 AND MPP-2

NOVEMBER 1979

Manual Number 50024273

Bendix reserves the right to make equipment changes and improvements which may not be reflected in this manual.

It is recommended that this document be read in its entirety before any attempt is made to operate or make any adjustment to the equipment.

Although every attempt has been made to present information which is both complete and current, variations either in equipment configurations or in equipment application, or both, make it impossible to cover all contingencies in a single document.

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The linear coordinate measurement system is based on the concept of measuring a workpiece by placing it on a "grid" formed by two perpendicular lines called axes (in figure 1-1 they are labeled X and Y). The point at which the axes cross is the zero-point. In figure 1-1, on the right side of zero, the X-axis measurement units (inches or millimeters) are positive numbers which become larger further right. On the left side of the X-axis zero-point, the measurement units are negative numbers. The Y-axis measuring scale is set up in an identical fashion; above zero the measurement units are positive numbers, and below zero they are negative numbers.

Measurements are made by counting the number of measuring units from the zero-point along an axis. For example, in the upper right corner of figure 1-1, is a rectangle and to measure the width of the bottom of the rectangle the distance from zero to point A on the X-axis is noted. In this case, the "X-coordinate" of point A is +4.5. Next, the distance from zero to point B is noted; it is +6.5. The width of the bottom of the rectangle is the difference between the point A and point B coordinates, i.e.: 6.5 - 4.5 = 2.0. The length of the side of the rectangle is found in the same manner by calculating the difference between coordinates on the Y-axis. Point C is located at +6.5 and point A is located at +4.0 on the Y-axis. The length of the side of the rectangle is, therefore: 6.5 - 4.0 = 2.5.

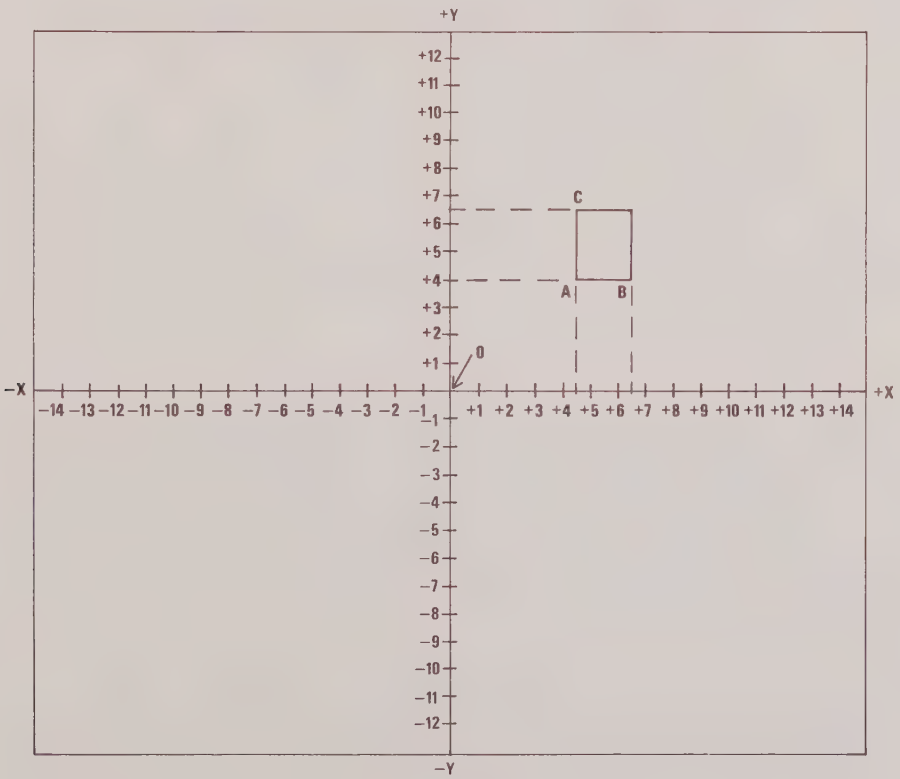


Figure 1-1. Illustration of X and Y Axes

A measurement system with two axes is sufficient for measuring in two dimensions, i.e., the length and width of a workpiece. However, to measure in three dimensions (length, width and height), a third axis must be added to the system. As shown in figure 1-2, this axis labeled Z, is perpendicular to the XY surface (called a plane) and it crosses the X and Y axes at the zero-point. The portion of the Z-axis above the XY plane is positive and the portion below the XY plane is negative. Measuring the height of an object along the Z-axis is done in the same manner as measuring length and width on the X and Y axes, i.e., the number of measurement units are counted from the zero point.

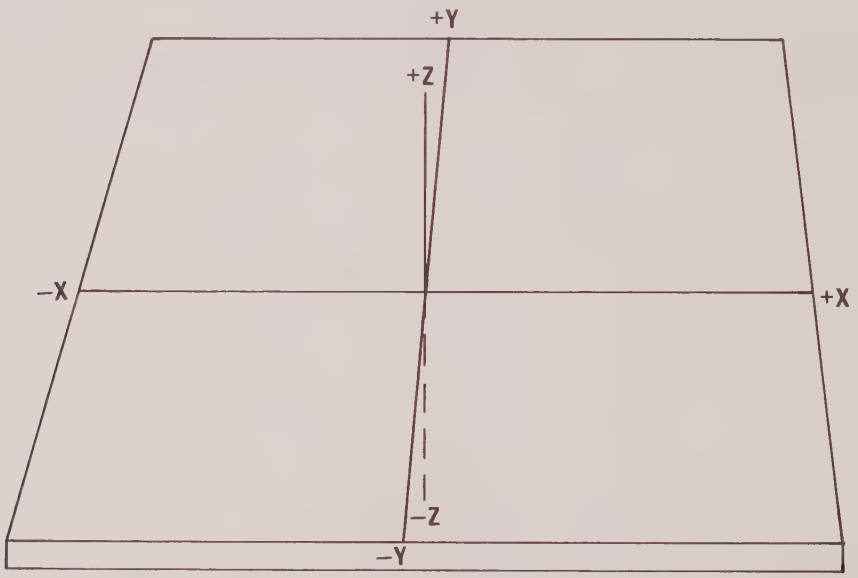


Figure 1-2. Illustration of X, Y, and Z Axes

Many measuring tasks may be readily accomplished using the linear axis measuring system, but some workpiece features, such as the bolt-hole circle shown in figure 1-3, may be more easily and efficiently measured using the polar coordinate system. This system is based on the idea that any point or "pole" is surrounded by an infinite number of concentric circles. The distance from the pole to a point on the circumference of one of these circles is called a radius. In the polar coordinate system, the length of a radius (in millimeters or inches) and the degrees of angle formed by two radii are used to define measurements.

For example, in the figure 1-3 bolt-hole circle, the measurement task is to determine whether all the bolt-holes are evenly spaced at 60 degree intervals around the central bore and whether they are all at the same, 12-inch distance from the bore center. To use the polar coordinate system in this instance, the center of the bore is defined as the pole from which measurements will be made. The radius of the circle which lies on the positive side of the X-axis is defined as the 0-degree radius. In this case, that radius connects

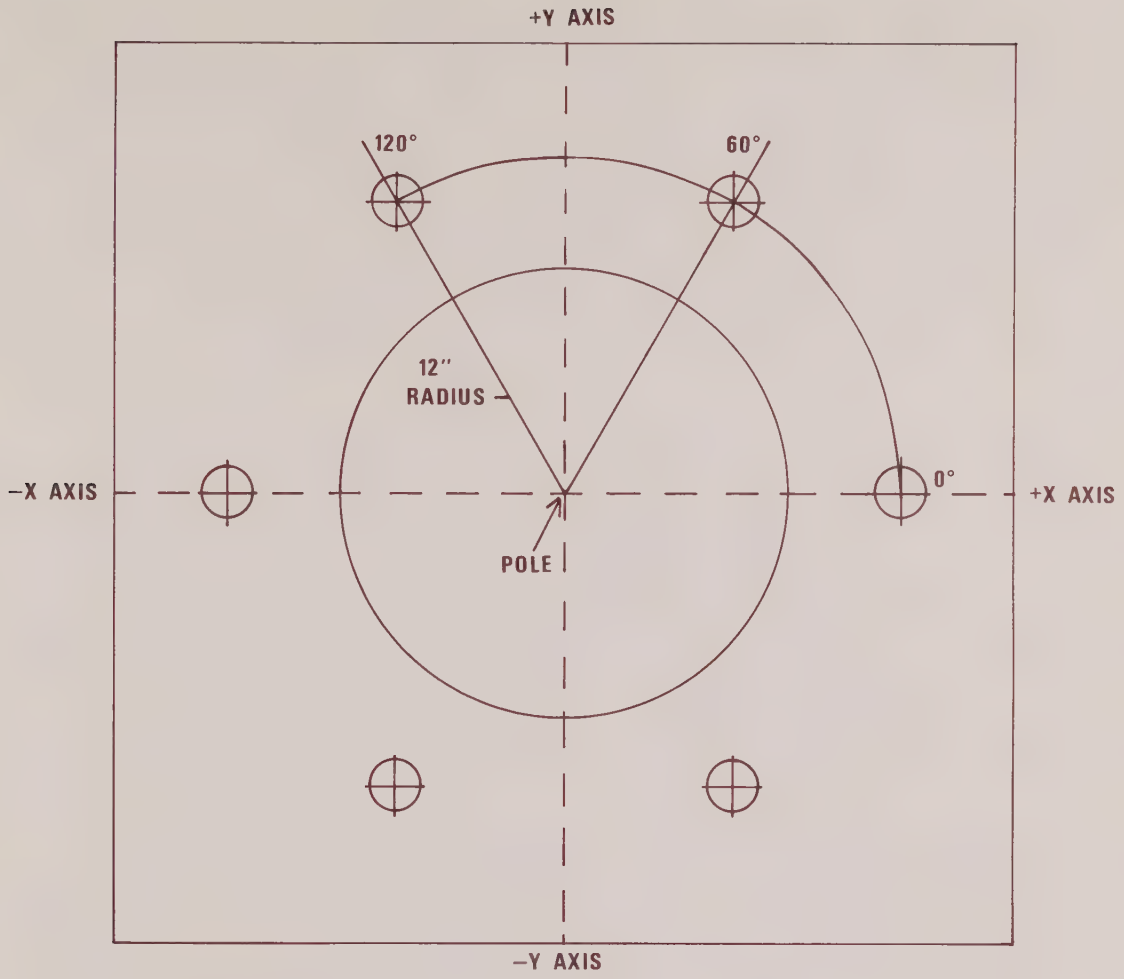


Figure 1-3.
Illustration of Polar Coordinate Measurement

the pole to the center of the bolt hole positioned at 3 o'clock in the figure. The number of degrees from the 0-degree radius to the radius connecting the next bolt hole center and the pole is measured to determine if the angle is 60 degrees, and so forth around the bolt hole-circle. Such measurements determine if the holes are evenly spaced around the pole; to determine if they are all at an equal distance from the pole, each radius passing from the pole to a bolt-hole center would simply be measured in inches or millimeters.

Calculating angles, or any other measurements, by hand is obviously a tedious, time-consuming and error-prone undertaking. It is for these reasons that the Measurement Pre-Processor (MPP) was developed as an integral part of the Cordax Coordinate Measuring System to instantly perform measurement calculations at the touch of a button.

Cordax machines have the capability to perform linear and polar measurements. Although no labeled lines and measurement scales appear on a Cordax machine to visually represent the X, Y, Z, and W (rotary) axes, they are present in the electronics of the system. As shown in figure 1-4, on the Cordax vertical arm machines, the worktable surface represents the XY plane with the X-axis running left to right, negative to positive, and the Y-axis running front to back, negative to positive. The vertical arm which holds the measuring probe represents the Z-axis with the negative side of the Z-axis below the XY plane, and the positive Z-axis above the XY plane. In addition to traveling up and down the Z-axis, the vertical arm moves left, right, backward and forward along the X and Y axes and the measuring probe position in relation to each of the axes is electronically tracked and displayed on the MPP.

On Cordax horizontal arm machines, the three linear axes are in a different configuration, as shown in figure 1-5. The X-axis is represented by the left/right movement of the column which carries the horizontal arm where the measuring probe is mounted. The left side of the X-axis is positive and the right side is negative. The Y-axis is represented by the up and downward movement of the arm on the column, with the upward movement in the positive direction and the downward movement in the negative direction. The Z-axis is represented by the front to back centerline of the setup plate. The setup plate is moving in a positive direction when it travels toward the horizontal arm and in a negative direction when it travels away from the arm. For horizontal arm machines, just like their vertical arm counterparts, the position of the probe in relation to the axes is tracked and displayed on the MPP.

Early versions of coordinate measuring machines had simple digital counters which tracked the position of the measuring probe, but did not provide data processing capabilities. These systems required skill and considerable time to achieve the same measurements which can be accomplished more quickly and efficiently with a Measurement Pre-Processor equipped system. For example, with the early systems, the operator was responsible for ensuring that workpiece axes or reference lines were precisely parallel to the machine axes. And, after alignment when measurements were being made, the operator had to relate measurements on part prints to measurements along the coordinate measuring machine axes. With the MPP, the operator can set the workpiece askew on the Cordax machine, record a set of reference points to inform the

MPP of the actual position of the part in relation to the machine axes and the MPP will automatically align the part to the Cordax machine axes. That is, the MPP will not cause the part to move so that it is physically aligned to the machine axes, but all readings displayed on the MPP will be mathematically compensated for the physical misalignment. Further, the MPP may be preset before measurements are taken so that the readings displayed will correspond to measurements of a workpiece as noted on a part print. These features in addition to many others listed by model number in table 1-1 make the measuring process simpler, faster and more accurate than ever before.

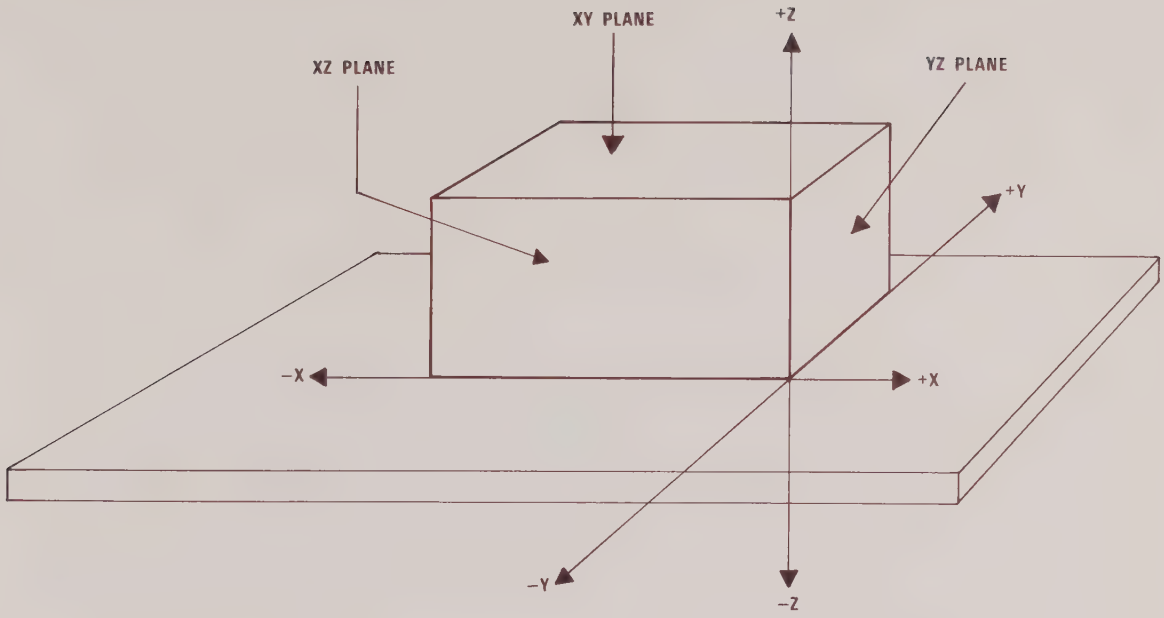


Figure 1-4. Vertical Arm Machine Working Planes

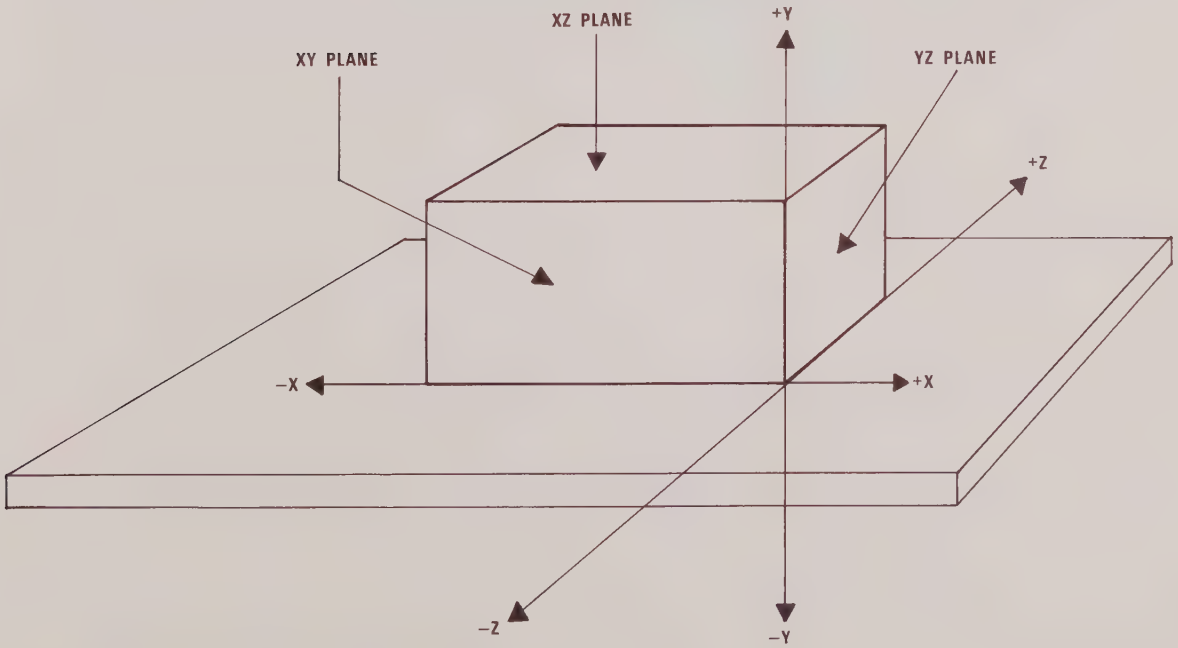


Figure 1-5. Horizontal Arm Machine Working Planes

The basic steps in the utilization of the MPP as described in this manual are:

1. Understanding the operation of the controls and indicators.

2. Part alignment.

3. Establishing workpiece reference points from which measurements are made.

4. Measurement procedures.

This manual describes these steps for three models of the Measurement Pre-Processor, the Models MPP, MPP-1 and MPP-2. The physical features and basic operational concepts are identical for all three models, but beyond that point, the capabilities of the Models MPP-1 and MPP-2 sharply diverge from those of the Model MPP. For that reason, headings within sections indicate the relevance of a particular sub-section to specific models. Before using the system, operators of a Model MPP should read through section 7, operators of a Model MPP-1 should read through section 11 and operators of an MPP-2 should read through section 12. In addition, all operators should become familiar with sections 13 and 14 which deal with maintenance, trouble-shooting and service.

This manual assumes that the operator will have a working knowledge of the coordinate measuring system and the physical features of the Cordax machine. It is not assumed here that the operator will have prior knowledge of data processing; by following the step by step instructions he or she should be able to perform all but the most special of applications with the MPP. In cases where special applications are desired which are not described in this manual, Bendix sales representatives should be contacted.

Table 1-1. MPP Features by Model

MODEL MPP*

- Automatic diagnostics on start-up
- Automatic part alignment in XY plane
- Metric/Inch conversion
- Reset/Preset
- Omniprobe deflection freezes readout

MODEL MPP-1

All the Model MPP features plus:

- Automatic part alignment in any one of the three working planes
- Set and modify offset angle function
- Three point diameter measurement and center-find (ID or OD)
- Conversion to polar coordinate tracking and display
- Selection of working plane
- Save/Recall/Set/Move reference functions
- Absolute or incremental dimensions
- Rigid probe reorientation
- Probe diameter compensation
- Deviation calculation
- Out-of-tolerance calculation
- True position calculation
- Repeat measurement function permits measurement sequence storage and recall
- Menu type selection of desired function eliminating need to program part
- Programmable display time
- Automatic detection and display of error codes for invalid keyboard entries

MODEL MPP-2

All the Model MPP-1 features plus:

- Interface with input/output device
- Touch probe reorientation
- Three axis auto-alignment
- Multi-point diameter and center-find
- Pattern center-find

*Model MPP may be interfaced to the PDP-8 minicomputer.

SECTION 2. THE MPP CONTROLS AND INDICATORS

2-1. DIFFERENCES AMONG MPP MODELS

The controls and indicators located on the front panel of the MPP are identical for Models MPP, MPP-1, and MPP-2. There is, however, a distinction in the operability of the display. The only operable rows of the Model MPP display are those which are connected to a measuring machine axis. On Models MPP-1 and MPP-2, all four axis rows of the display are always operable because they are used for showing auxiliary data in addition to probe position data.

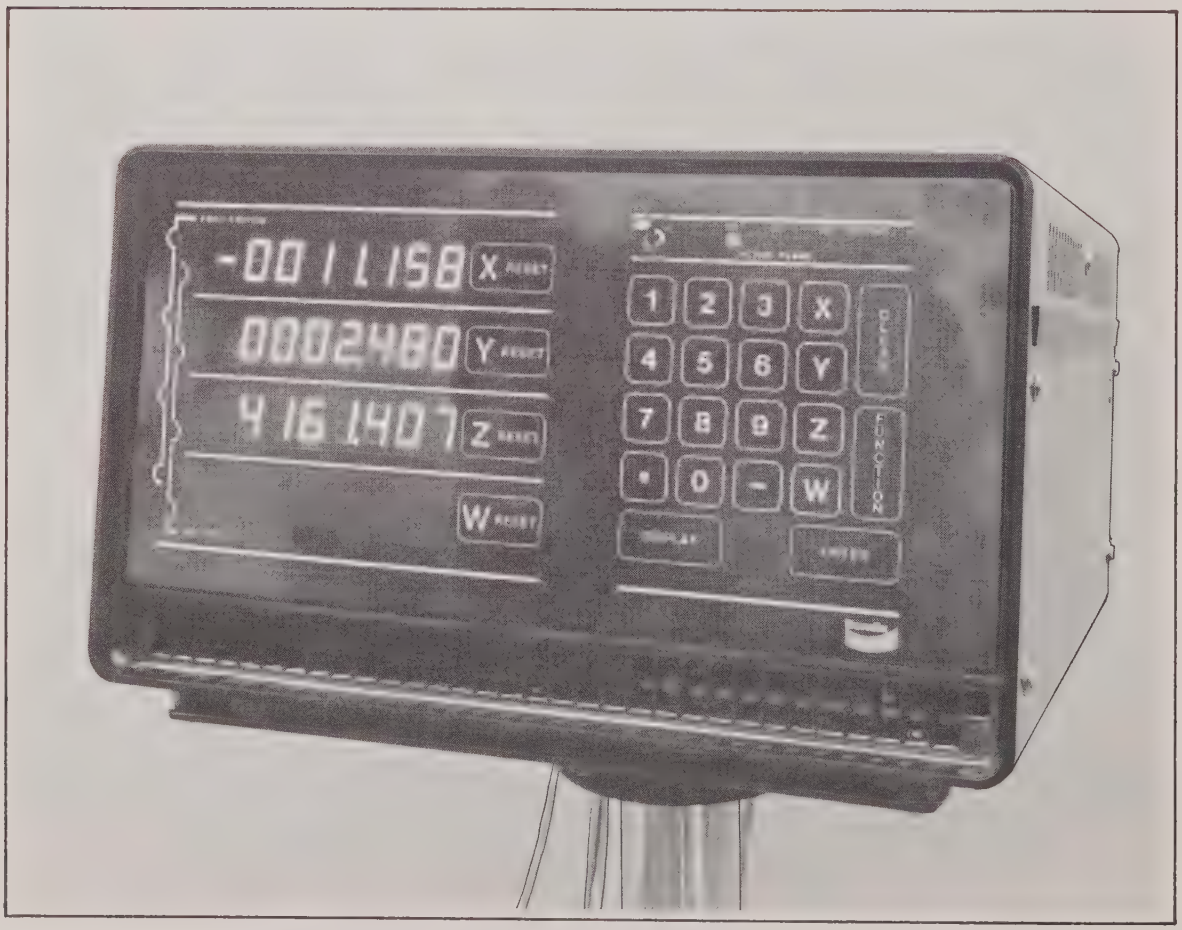


Figure 2-1. The MPP Front Panel

2-2. FRONT PANEL INDICATORS

2-2.1 Display

The primary function of the digital display, pictured in figure 2-1, is to show the position coordinates of the measuring probe. The top three rows display the linear coordinates of the X , Y, and Z axes. The fourth row represents the W or rotary axis and, when a rotary table is a part of the measuring machine system, it displays the table rotation angle, in degrees. The display is also utilized for showing auxiliary data, such as error messages.

Each row of the display can show a maximum of seven numeric characters, a minus sign, and a decimal point. When a negative number is displayed, a minus sign is shown; when a positive number is displayed, the leftmost digit of the display is blank. As the measuring probe is moved along an axis, the display is updated eight times per second.

The decimal point location for numbers shown on the display depends on the resolution of the Cordax machine axes and the position of the MM/INCH switch (described in section 2-3.1). Table 2-1 lists various machine resolutions and the corresponding MPP decimal place location called the display resolution.

The inch measuring machine resolutions in table 2-1 are an odd fraction in all cases (approximately .00004 or .0004). Because many applications do not require this resolution and, in fact, it would be bothersome, two display resolutions have been provided for inches. These are identified as "normal" and "extended" in the table. In the normal inch display the least significant digit is not displayed. To switch from one of these display resolutions to the other, press the DISPLAY keypad.

In all cases the displayed value has been rounded to the display resolution. This is true for metric and inch units since fractional values may be introduced either through the measurement machine resolution or by part alignment calculations. If the next digit beyond the displayed resolution is less than five, it is ignored; otherwise the least significant digit of the display value is incremented.

Table 2-1. Cordax Machine and MPP Display Resolutions

Measuring System	Measurement Machine Resolution	Display Resolution*		
		mm	Inch (Normal)	Inch (Extended)
Cordax Machines, Metric Gratings	.001 mm .00003937007874 in.	.001	.0001	.00001
Cordax Spar Systems	.001 mm .00003937007874 in.	.005	.0002	.00020
635-LPR Encoders Software Version 1	.01 mm .00039370078740 in.	.010	.0010	.00010
635-LPR Encoders Software Version 2	.01 mm .00039370078740 in.	.010	.0005	.00100
Cordax Machines, Inch Gratings	.00150583333330 mm .00004166666667 in.	.001	.0001	.00001
Rotary tables for Horizontal Arm Machines	.00041666666670 deg.	.001 degrees		
	.00100000000000 deg.	.001 degrees		
	.00005000000000 deg.	.001 degrees		

*The measurement machine resolution is the smallest unit of movement that can be detected by the hardware. The display resolution is the smallest unit that can be displayed. Since the displayed values may include axis scaling and alignment corrections, movement of a single machine unit (count) may result in a change of several units in the displayed value or in no change at all.

2-2.2 Status Indicators

There are four sets of status indicators on the front panel of the MPP which are labeled FAULT-CAUTION, AUX DATA, ACTIVE PLANE and OFFSET.

The FAULT-CAUTION indicators are a vertical row of lights on the left side of the front panel. To the right of these lights is a second vertical row of AUX DATA lights. There is one of each of these lights for each row of the display.

The yellow FAULT-CAUTION lights signal that conditions are occurring which might cause a system miscount. These conditions may occur, for example, as a result of a power fluctuation, a misadjustment of the reading head amplifier, or a too rapid movement of the measuring probe. Once lit, a FAULT-CAUTION light remains on until any axis reset keypad is pressed.

The red AUX DATA (auxiliary data) lights are lit anytime the data being displayed are other than linear coordinates of the current probe position.

The red ACTIVE PLANE indicators are a horizontal row of three lights on the upper right corner of the front panel. One of these lights is always lit to indicate the plane in which planar calculations will be made. In the Model MPP, only the XY active plane light will be operative.

To the right of the three ACTIVE PLANE indicators is a red light labeled OFFSET. This indicator is lit whenever the Models MPP-1 and MPP-2 automatic part alignment feature is active. Also, in response to certain programmed functions, the OFFSET light flashes to indicate that the MPP is ready and waiting to accept input data.

2-2.3 Audible Indicator

The MPP provides audio feedback to the operator by emitting a single "beep" sound whenever a front panel keypad or the footswitch is pressed properly or when an Omniprobe contact has been recognized.

In instances when the MPP recognizes a keypad depression or switch contact as illegal, it disregards the illegal input and causes the audible indicator to sound a series of beeps.

2-3. FRONT PANEL CONTROLS

2-3.1. Millimeter/Inch Conversion Switch

The MM/INCH conversion toggle switch located at the top center of the front panel is used to change the coordinates shown on the display from millimeters to inches and vice versa. When the switch is flipped the audible indicator will sound a beep and the displayed values will be instantly converted to the newly set measurement unit for all linear axes. This switch does not affect the rotary axis display row.

2-3.2 Reset Keypads

A vertical row of axis reset keypads is located to the right of the display. Pressing one of these keypads resets the corresponding row of the display to zero and causes the audible indicator to emit a beep. Also, resetting an axis causes any system fault condition (signaled by a yellow FAULT-CAUTION light) to be cleared.

2-3.3 Data Entry Keypads

The right half of the front panel contains an array of twenty keypads which are used for entering data and commands into the MPP. There are 12 keypads for entering numeric data: the digits zero through nine, a minus sign and decimal point. To the right of the numeric keys is a vertical row of four axis letter keypads labeled, top to bottom, X, Y, Z, and W. To the right of the axis letter keypads are the CLEAR and FUNCTION keys, and below the numeric keys are the DISPLAY and ENTER keys.

2-4. OTHER CONTROLS

2-4.1 Power Cord

The power cord exits the MPP from the bottom, center rear of the chassis. It must be plugged into a grounded three-wire receptacle which supplies power of the voltage and frequency indicated on the data tag on the back of the chassis.

2-4.2 Power/Off Switch and Circuit Breaker

The POWER/OFF switch, located at the top, center of the rear of the MPP, is a combination power switch and circuit breaker. To turn on the MPP, the switch is lifted; to turn off the unit, the switch is pressed. This switch also automatically interrupts power in the event of a line current overload which may be caused by an excessive voltage supply or by a component failure inside the MPP.

CAUTION

> If the POWER/OFF switch fails to remain in the POWER position when lifted, do not hold it there or damage to the MPP may result. Refer to troubleshooting information in section 13.

SECTION 3. FOOTSWITCH AND MEASURING PROBE: HOW THE MPP RECORDS DATA

During the measurement process, a point is recorded by the MPP as a result of two actions by the operator. First, the object being measured is contacted by the measuring probe. Second, while the probe is contacting the workpiece, a footswitch pedal is pressed and released.

The type of measuring probe used is dependent upon the type of machine available and the measuring task at hand. The vertical arm measuring machines can utilize either an electronic omnidirectional probe or any of an array of rigid measuring probes with tips in the form of balls, tapers, discs, and other shapes. Horizontal arm measuring machines use an omnidirectional probe.

Figure 3-1 pictures a dozen different rigid probes for use with vertical arm measuring machines. The probe tips are integrally connected through a solid shank to a male Morse taper which is inserted and removed from a matching taper socket in the vertical arm of the measuring machine.

Rigid probes are called "manual" measuring devices because they are not directly, electronically connected to the MPP itself. The omnidirectional probe (Omniprobe) shown in figure 3-2, available for use with both vertical and horizontal arm measuring machines, is electronically connected by a cable to the rear of the MPP chassis, and is therefore designated as an "automatic" probe.

The Omniprobe is called a "flexible" or "touch" probe because all of its interchangeable tips are designed to deflect upon contact with a workpiece. The probe is termed "omnidirectional" because, from the at-rest position, the tip can deflect in any angular direction. In other words, if the Omniprobe tip is visualized as the center point of a circle, the tip is capable of deflecting along any of the radii of that circle, as well as, in an upward direction.

During the measurement process, the instant the Omniprobe tip contacts a workpiece, i.e., leaves the at-rest position, the MPP "freezes" on the display the coordinates of the point of initial probe tip/workpiece contact. The display will remain "frozen" until the probe tip returns to the at-rest position. At the instant deflection occurs, the MPP stores the "frozen" coordinates in a temporary memory, and, when the footswitch is pressed, the "frozen" coordinates are also stored in a more permanent memory from which they may be recalled for later use. The "frozen" coordinates will be erased from the temporary memory only after the probe tip has been returned to the at-rest position and deflected a second time or until the power is turned off. However, to avoid inadvertantly losing the coordinates from the temporary memory (because the probe tip is accidentally redeflected) it is recommended that the footswitch be pressed immediately after the probe tip is initially deflected and is still in contact with the workpiece.

Two additional events occur when the Omniprobe tip is deflected. First, the audible indicator sounds a beep. Second, the red light on the probe body goes out. This light is always lit when the system is on and operational and the probe tip is in the at-rest position.

Operation of the footswitch differs slightly between manual mode (rigid probes) and the automatic mode (Omniprobe). When using a manual probe, touching the workpiece with the probe does not cause the probe tip coordinates to be stored in a temporary memory. In this case, after the probe has been positioned, pressing the footswtich causes a beep to be sounded and the probe position coordinates to be stored directly into an MPP memory which will retain them for later usage. A second depression of the footswitch causes a second set of coordinates to be recorded, and does not erase the first set. If the footswitch is pressed twice with the manual probe in the same position, two identical sets of coordinates will be recorded. This is different from the Omniprobe operation where a second depression of the footswitch without moving the probe causes a series of beeps to be sounded and the MPP refuses to record a second, identical set of coordinates. To record the same point twice with the Omniprobe, the probe tip must be deflected against the point once, the footswitch pressed, the tip returned to the at-rest position and deflected a second time followed by a second depression of the footswitch.

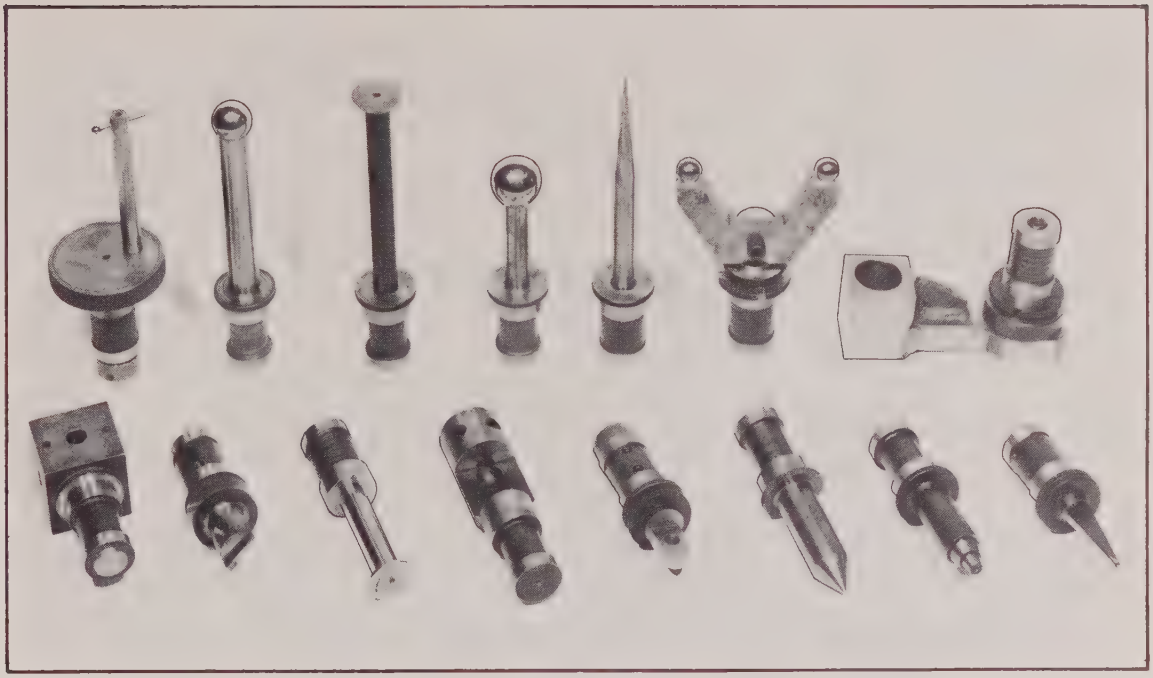


Figure 3-1. Examples of Rigid Measuring Probes

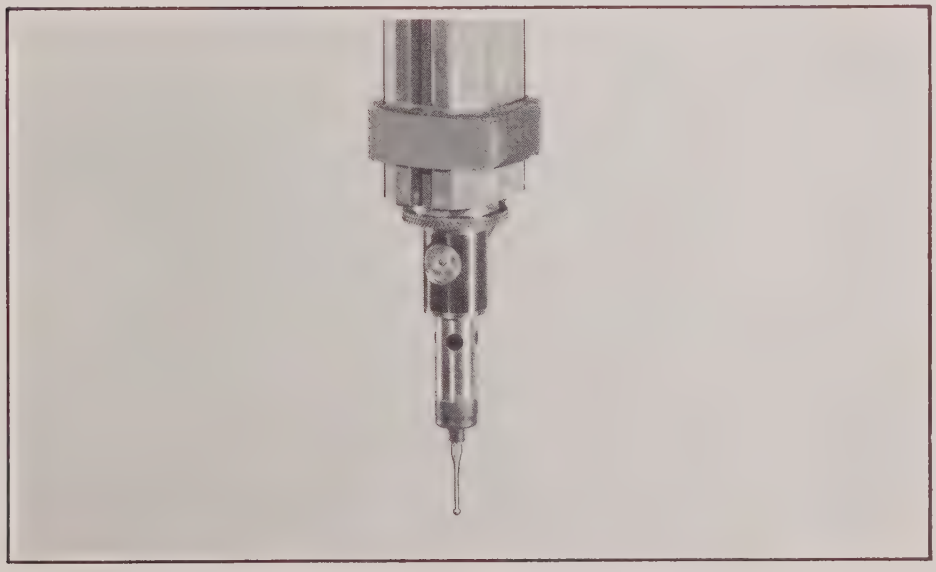


Figure 3-2. The Omniprobe, Model TP2

SECTION 4. COMMUNICATING WITH THE MPP

The operator communicates with the MPP by entering "commands" through the front panel keypads. Commands for the MPP consist of a series of numbers and letters arranged in a specific way. Learning to enter commands is accomplished by, first, understanding the operation of the keypads; second, by learning a short set of rules about the elements and structure of commands, and third, by becoming familiar with the set of operating instructions, called "functions" which are permanently stored in the MPP memory.

4-1. USING THE KEYPADS TO ISSUE COMMANDS

The number, decimal point, negative sign, and axis letter keypads are always used in conjunction with the FUNCTION, ENTER, and DISPLAY keypads when entering a command.

The FUNCTION keypad (abbreviated F) is used to recall from the MPP memory operating instructions which have been permanently stored there. The number of these instructions, or functions, stored in the memory varies with the MPP model, as indicated in the Appendix A function list. Each function has its own number and, therefore, to recall a function from memory, the F keypad is pressed, followed by the function number (e.g. F9, F41 or F alone as a shortcut for FØ).

The ENTER and DISPLAY keypads (abbreviated E and D, respectively) are command "terminators." Every command must end with a depression of one of these two keypads. The specific usage of the E and D keypads is described in later examples; but, in general, when a command is terminated with the D keypad, the MPP executes the command and displays the results. When a command ends with the E keypad, the MPP executes the command but does not display any command results.

Directly to the right of the display is a vertical row of four keypads labeled X RESET, Y RESET, Z RESET, and W RESET. Pressing one of these keypads resets the corresponding row of the display to zeros. Also, pressing any of the reset keypads turns off any FAULT-CAUTION lights which are lit. When the MPP is actively processing data, it may be too busy to respond to a reset keypad depression. When this occurs, a series of beeps will be sounded and the reset keypad should be pressed again after a few seconds have elapsed.

Pressing the CLEAR keypad (abbreviated C) causes the MPP to ignore all keypad depressions since the previous depression of an E or D keypad; i.e. pressing C erases an incorrectly entered command, or parts thereof. In addition, pressing C causes any temporary data display or error message display to be canceled.

4-2. THE PARTS AND STRUCTURE OF COMMANDS

A command usually has three parts: data, function selection, and terminator. The data part of a command need not always be used, but, when it, it is either a number, or one or more axis letters (e.g., X1.03, Y15Z73.25). The function selection part of a command consists of an F and the number of the function, e.g., F9, F41 or simply F as a short cut for FØ. The terminator part of a command is either an E or a D, depending upon the specific command.

Following are eight rules to be used in composing a command:

1. Each axis keypad (X, Y, Z, and W) may be pressed only once in a command. For example:

Legal Command:	X4F2E
Illegal Command:	X4X3F2E

2. If the first keypad pressed in a command is a numeric key, no axis letter keypad may be pressed in the command. For example:

Legal Commands:	X41F2E .5F9E
Illegal Command:	41XF2E

3. The last keypad pressed in a command must be either the E or D keypad. For example:

Legal Commands:	X.5F2E 100F14D
Illegal Commands:	X.5F2 100F14

4. The function number must be the last item in a command before the E or D keypad depression. For example:

Legal Command	X.5F2E
Illegal Command:	F2X.5E

5. The minus sign may only be the first digit of any number and it must be followed by at least one digit or a decimal place and at least one digit. For example:

Legal Commands:	X-4F2E X-.5F2E
Illegal Commands:	X-E X2-5F2E

6. The decimal point may only be entered once per number and must follow or precede a digit. For example:

Legal Command:	X.54F2E
	X5.4F2E
Illegal Commands:	X.F2E
	X5..2E

7. During a temporary display interval (when the results of a command execution are being displayed) no commands may be entered.

8. No more than forty characters may be entered in a command. If more than forty characters are entered in one command, the MPP automatically interprets the fortieth keypad depression as a depression of the E keypad and attempts to process the command.

4-3. BECOMING FAMILIAR WITH THE MPP FUNCTIONS LIST

Appendix A lists, by MPP model, the functions which may be selected for inclusion in commands. All of the functions are elaborated upon in later sections which describe various MPP operations. Familiarity with each of the functions is best gained by reading about and working with them in the process of learning to operate the Cordax system.

4-4. ERROR MESSAGES

As a sequence of keypads is pressed to enter a command, the MPP examines each keypad depression to ensure that the rules given in section 4-2 are not broken. If a keypad depression is acceptable, a single beep will be sounded. If a keypad depression is not acceptable, a rapid series of beeps will sound and the offending keypad depression will be ignored, allowing the operator to press the correct keypad and go on with the command entry.

Once a command is terminated by use of the E or D keypad, it is examined by the MPP to ensure that the data entered in the command is compatible with the selected function, the selected function exists in the system, and the command is correct for the current operating state of the MPP. If an error is found at this point, an error message is displayed in the X-axis row of the display. Error messages are described and listed in Appendix B.

SECTION 5. MPP START-UP AND AN EXERCISE FOR MPP OPERATORS

CAUTION

> The power switch on the rear of the MPP chassis is also a circuit breaker. Do not force the switch to remain in the POWER position or damage to the MPP may result. If the switch does not remain in the POWER position when released, refer to the troubleshooting information in section 13.

Immediately upon setting the POWER/OFF toggle switch on the rear of the chassis to the POWER position, the MPP automatically executes the following series of tests to determine the internal condition of the MPP:

Test 1. Random Access Memory (RAM): This test verifies that every data cell (bit) of the memory can be turned on and off.

Test 2. RAM Data Maintenance and Addressability: This test verifies that every byte (group of 8 bits) in the RAM is uniquely addressable and can maintain data for a reasonable length of time.

Test 3. Read Only Memory (ROM): This test verifies that the program code and fixed data area of the memory are readable and correctly installed.

Test 4. Keypad: This verifies that no keypad switches are stuck in a closed position.

Test 5. Compatible Peripherals: This test verifies than an input/output terminal and a PDP-8 minicomputer are not both interfaced to the MPP.

If the tests reveal no problems, the audible indicator sounds one or two beeps a few seconds after the power has been turned on, the display shows all zeros, and the FAULT-CAUTION and XY ACTIVE PLANE indicators are lit. To proceed with measurement operations push any one of the axis reset keypads to turn off the FAULT-CAUTION lights.

If one of the tests uncovers a problem, the test number appears in all digits of the top row of the display and the system firmware version number appears in all digits of the second row of the display. Also, the audible indicator beeps for approximately 30 seconds. If this occurs, note the information from the display and call for repair service (refer to section 14).

If it is desired to check the system firmware version number at some point when no problems exist, this may be done by pressing one of the front panel keypads and keeping it depressed while turning on power to the system. This action will cause the system to react as if it has failed Test 4 and the firmware version number will appear, as previously described, in the second row of the display. To clear this condition, turn the power off and then on again.

5-1. EXERCISE FOR BECOMING FAMILIAR WITH MPP OPERATION

The following exercise is designed to assist the operator who has read the first five sections of this manual in becoming familiar with the MPP controls and indicators and their interaction with the Cordax machine. Following, on the left, are a series of actions to be taken by the operator and, on the right, are the reactions which may be expected from the MPP and the Cordax machine.

Action	Reaction
1. Set the POWER/OFF switch on the back of the MPP chassis in the POWER position.	The MPP will run the self tests described in section 5 and will emit a beep or two. The display will show zeroes and the FAULT-CAUTION and XY ACTIVE PLANE lights will be lit.
2. Push any of the axes RESET keypads.	The MPP will sound a beep and the FAULT-CAUTION lights will go out.
3. Move the measuring probe in any direction desired.	The display will reflect the distance the probe moved from the power-up zero-point, in the measurement unit indicated on the MM/INCH switch.
4. Flip the MM/INCH switch.	The MPP will beep once and the display will instantly change to reflect, in the new measurement unit, the distance the probe was moved in step 3.
5. Press each of the axis RESET keypads.	A beep will sound as each keypad is pushed and each row of the display will be reset to zeroes.
6. Place an object on the Cordax worktable, move the probe in contact with it, and push the footswitch. If using the Model MPP-1 or MPP-2, write down the numbers showing on the display when the footswitch is pressed.	The display will show the distance the probe traveled from the step 5 RESET operation. If using an Omniprobe, the probe tip will deflect against the object on the table, the MPP will beep once, and the red light on the probe body will go out while the tip is deflected. When the footswitch is pressed, the MPP will beep once and record the coordinates of the probe location.
7. Move the probe away from the object on the table.	The display will track the probe movement.

8. Model MPP, go on to step 9. For Models MPP-1 or MPP-2, press the FUNCTION, 1, 8, and DISPLAY keypads to enter the command F18D which recalls for display the last recorded point (i.e., the point recorded in step 6).	The MPP will beep as each keypad is pressed. The AUX DATA lights will go on. The display will change, for 5 seconds, from showing the current position of the probe to showing the coordinates of the point recorded in step 6. At the end of the 5-second temporary display interval, the display will revert to showing the current probe position coordinates.
9. Press the keypads: 1, 2, 3, and X.	The MPP will beep as each keypad is pressed, then it will emit a series of beeps and ignore the keypad operations because they do not constitute a legal command.
10. Model MPP, turn off power. For Models MPP-1 and MPP-2, go on to step 11.	
11. Press the keypads: FUNCTION, 7, and ENTER to enter the command F7E.	As each keypad is pressed the MPP will beep, then the MPP will emit a series of beeps and all front panel lights will go out except for the X-axis row of the display which will show ERROR 11 because the MPP-1 or MPP-2 does not have the necessary information to execute the command entered.
12. Press CLEAR.	The MPP will beep and the display will stop showing the error message and return to showing probe position coordinates.
13. Turn off the power.	

SECTION 6. ALIGNMENT AND PROBE REORIENTATION PROCEDURES

6-1. OVERVIEW OF ALIGNMENT PROCEDURES

The first task in the measurement process is aligning the axes of a workpiece with the Cordax machine axes. Aligning a part means placing the part axes parallel to the measuring machine axes. Two axes are parallel when they are exactly the same distance apart all along their length. Workpiece axes are frequently indicated on part prints or inspection drawings; if they are not, they may be defined by the operator during the process of planning the measurement task.

Using a coordinate measuring machine not equipped with a Pre-Processor, it would be necessary to manually align the three workpiece axes with the three machine axes. With an MPP equipped system it is not necessary to manually align more than one of the three part and machine axes because each model of the MPP provides an automatic alignment capability. The Model MPP automatically aligns workpiece and machine X and Y axes; with the Model MPP-1 any two of the three machine and part axes may be automatically aligned and with a Model MPP-2 all three part and machine axes may be automatically aligned.

For example, to automatically align X and Y part and machine axes using a Model MPP with a Cordax vertical arm machine where the X and Y machine axes or XY plane is represented by the table top, the operator performs the following steps:

1. Places the part on the table with the axes unaligned.
2. Manually aligns (i.e., makes parallel) the part and machine Z-axes.
3. Records with the measuring probe a set of points along one part axis of the XY plane.
4. Enters a command which instructs the MPP to use the just-recorded points to align the X and Y workpiece and machine axes.

The points recorded in step three inform the MPP of the actual position of the workpiece axes in relation to the machine axes. When the MPP "aligns" the axes it does not cause the part to move so that they are physically aligned, but rather, it mathematically compensates for the physical misalignment throughout the measuring process such that all measurements recorded and/or displayed appear as if the part and machine axes are perfectly aligned.

Because of the progressively more sophisticated alignment capabilities of the Model MPP-2 over the Model MPP-1 and the Model MPP-1 over the Model MPP, the remainder of this chapter will guide the operator through the alignment process in a stepwise fashion. First described will be the preparatory steps necessary for performing two axis auto-alignment with any model. Next, the basic two axes alignment procedure will be described as it is performed with a Model MPP, and that will be followed by a description of the expanded two axis auto-alignment capabilities of the Models MPP-1 and MPP-2. Finally, the three axis auto-alignment capabilities of the Model MPP-2 will be described. To understand part alignment, the operator of a Model MPP need read only the section relevant to that model; the operator of a Model MPP-1 should read through the end of the two axes alignment description and the operator of an MPP-2 should read to the end of the chapter. At the end of each descriptive section is a list of steps detailing the commands and operator actions necessary to achieve alignment.

6-2. DEFINING WORKPIECE AXES

Section 1 describes the axes of the Cordax coordinate measuring system. Because the definition of alignment is to make parallel the machine axes and workpiece axes, this section will describe how workpiece axes are defined.

Determining where the part axes are located and how they are labeled are preparatory steps to aligning the part and machine axes and setting the Cordax machine so that the zero reference point of the machine axes will be the same as the zero point the operator has chosen on the workpiece.

Workpiece axes are defined using the same rules which apply to the measuring machine axes, i.e., they are always straight lines which are perpendicular (at a 90-degree angle) to each other. Where the operator decides to place the axes on a workpiece is generally dependent upon the measurement task at hand. For example, if the majority of measurements to be made on a part relate to one part feature, it is efficient to place the axes so that they cross at that part feature. The reason for this is that the point where the axes cross is the zero-point from which distances will be measured and fewer calculations are required to arrive at the measured distance when starting from zero.

Once the location of the workpiece axes is determined they must be labeled X, Y, and Z. To do this, first determine how the part will be positioned on the Cordax machine table and then label the workpiece axes after the machine axes to which they are closest. For example, in figure 6-1 the workpiece axes closest to the machine X-axis has been labeled X. Once the workpiece axes are defined, it may be useful to label the part print with the location and names of the axes.

It should be noted that it is not necessary to physically draw the workpiece axes on a part, unless doing so is helpful to the operator.

Figures 6-1 and 6-2 illustrate two different placements of part axes on the same workpiece. In figure 6-1, the measurement task is to determine the distance from the corner of the part in the foreground to the centers of the bolt holes. In this case, it is efficient to make the part axes the edges of the part, causing them to cross at the corner from which measurements will be made.

In figure 6-2, the measurement task is to measure the location of four of the bolt holes in relation to the fifth bolt hole, and for that reason, the axes have been defined as crossing at the center of the hole from which the measurements will originate. (Establishing the zero reference point using the MPP is described in detail in section 7.)

6-3. MANUALLY ALIGNING A WORKPIECE AXIS TO A MACHINE AXIS

Before two axis auto-alignment can be accomplished, the workpiece must be manually aligned to the third axis. This is always true for the Models MPP and MPP-1; with an MPP-2 it is not necessary if the three axis auto-alignment capability is utilized.

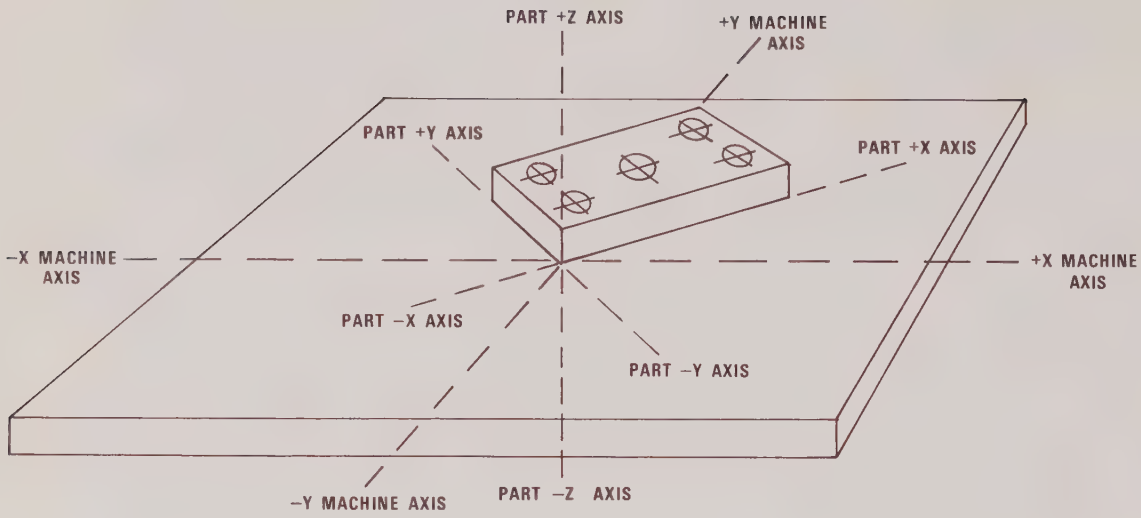


Figure 6-1. Workpiece Axes Shown as the Edges of a Workpiece

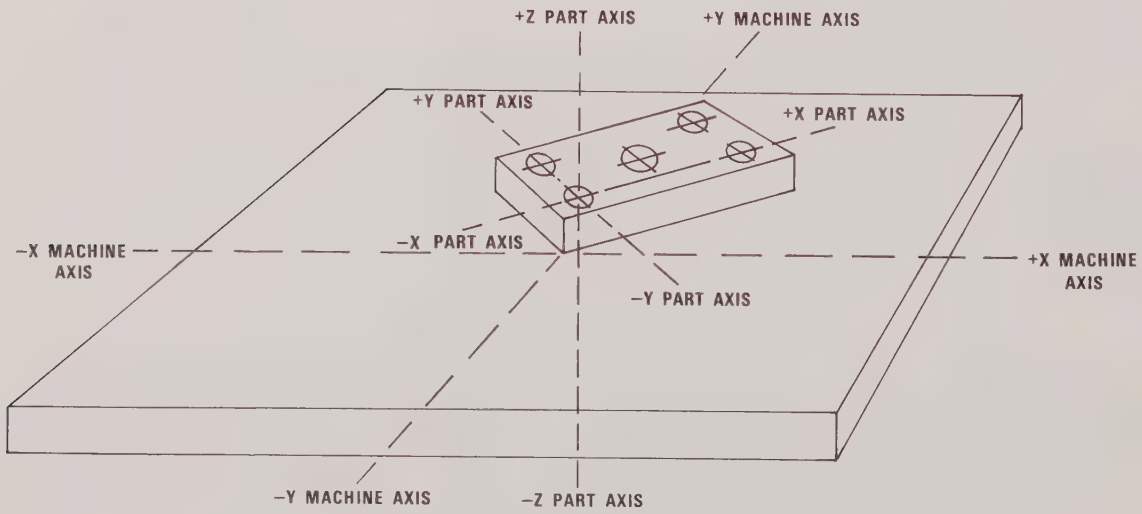


Figure 6-2. Workpiece Axes Shown as Defined by a Workpiece Feature

Given that all axes of a coordinate measuring machine are perpendicular to each other, and if the part axes are properly defined as perpendicular to each other, making any of the XY, YZ or XZ part planes parallel to its' corresponding machine plane will cause the third machine and part axes to be parallel also. For example, on a Cordax vertical arm machine where the tabletop represents the XY plane, and it is desired to auto-align a part in that plane, the Z (vertical) axis of the part (as defined by the operator) must first be made parallel with the X-axis of the machine. To do this, the operator would secure an irregularly shaped part with clamps to the Cordax machine table, or set a part, such as the cube pictured in figure 6-3, on the table. The Z-axis alignment is then checked by sampling a number of points on the XY plane of the part. Figure 6-3 has four such points labeled A, B, C, D. The operator would first touch the probe to point A and while the probe is in contact with the part, push the Z axis reset buttons. This action sets the Z row of the display to zeroes. Next, the operator would move the probe to point B. If at this location, the Z row of the display continues to read zero, the side of the part between points A and B is parallel to the same line on the XY plane of the machine. The operator would then continue to move the probe around the XY part plane while observing the row of the display to see whether the numbers shown remain at zeroes.

If the Z row of the display shows numbers other than zero while the probe is contacting some point on the XY part plane, the part and machine XY planes are not parallel. The operator would then manually adjust the position of the part to make the planes parallel, once again contact the part XY plane with the probe, reset the Z row of the display and observe the display while moving the probe around the XY part plane. This series of actions would be repeated until the XY planes of the part and machine were made parallel.

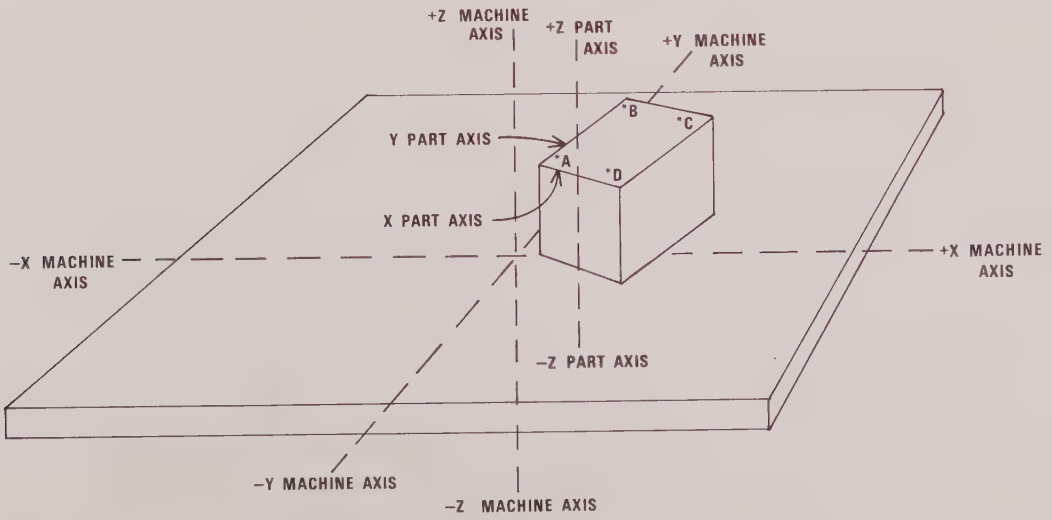


Figure 6-3. Illustration of Manual Part and Machine Axes Alignment

6-4. DESCRIPTION OF THE TWO AXIS AUTO-ALIGNMENT CAPABILITY OF THE MODEL MPP

After the workpiece and machine axes which are perpendicular to the alignment plane have been made parallel, the next step in the process is to give the MPP information on the amount of physical misalignment between the machine and part axes in the alignment or active plane. This misalignment is measured as the angle formed by the point where a machine and a workpiece axis cross and it is called the "offset" angle. The offset angle is illustrated in figure 6-4 which shows a rectangular workpiece on the table top (XY plane) of a Cordax vertical arm machine. This workpiece is shown as having been previously aligned with the Z-axis.

The offset angle is pictured in figure 6-4 between the +X machine and +X part axes. This placement of the offset angle is a matter of convention which will be followed throughout this manual. The offset angle could be measured between the Y part and machine axes, but it is customary to measure it between the positive ends of the first named axis in the alignment plane. For example, in figure 6-4 alignment is taking place in the XY plane and therefore the positive X axes are chosen for measuring the offset angle.

Whether the offset angle is positive or negative is determined by the direction it is measured from the machine axis which forms one side of the angle. The angle is positive if it is measured counterclockwise from the machine axis; if the angle is measured clockwise from the machine axis, it is negative. For example, in figure 6-4, the offset angle is measured in a counterclockwise direction from the +X machine axis and is therefore a positive angle.

In the figure 6-4 example, auto-alignment is achieved in two steps. First, the offset angle is measured by recording two points along the part X axis, or a line parallel to it, with the measuring probe. (For example, in figure 6-2 where the part axes are defined as running between bores and are parallel to the edges of the part, the points recorded for offset angle measurement may be taken along the part axis or along the edge of the part.) In figure 6-4 these points are labeled A and B. The order in which the points are recorded is not important. Next, a command is issued to the MPP to compute and store the offset angle. After this command has been executed, the OFFSET light in the upper right corner of the display will be lit to indicate that all subsequent measurements (until the offset correction is canceled) will be mathematically compensated such that they will appear on the display as if the X and Y part axes were positioned exactly parallel to the X and Y machine axes. Once the OFFSET light comes on, the alignment process is complete.

Operators of the Model MPP should note the following:

1. The Model MPP can perform auto-alignment only in the XY plane, therefore, the XY plane is always the "active" plane and the XY ACTIVE PLANE light on the upper right of the display is the only one of the three which will ever be lit for this MPP model. The XY plane of vertical arm machines is represented by the table top. The XY plane of horizontal arm machines is the vertical plane perpendicular to the arm.

2. The Model MPP can measure an offset angle no larger than 90 degrees. This means that a part should be placed such that the part and machine axes are misaligned no more than one quarter of a rotation of the part around the Z-axis.

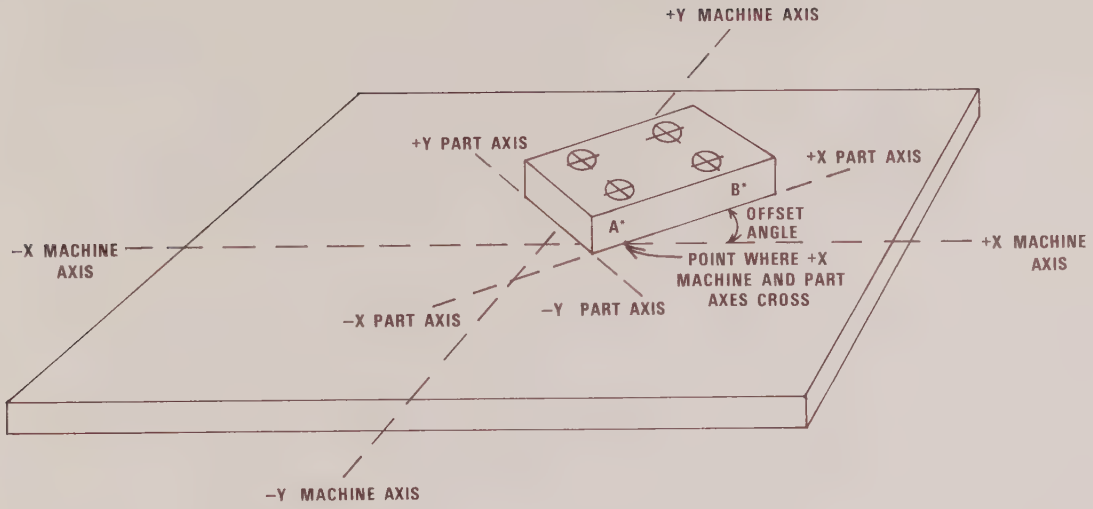


Figure 6-4. Illustration of Workpiece Alignment in the XY Plane

6-4.1 Summary of Steps in Performing XY Plane Auto-Alignment with the Model MPP

1. Position the workpiece such that the positive X machine and part axes are not misaligned more than 90 degrees.

2. Manually align the Z workpiece and machine axes.

3. Record with the measuring probe (as described in section 3) two points along the positive X-axis of the part or along a line parallel to the +X part axis.

4. Command the MPP to execute Function Ø (Calculate and Store the Offset Angle) by pressing the keypads:

FØE or FE

FE may be used instead of FØE because whenever the MPP encounters an F without a following number it assumes the F to mean the same as FØ.

After the command has been executed the OFFSET light on the display will be lit and the alignment procedure for the Model MPP has been completed.

When it is desired to cancel the offset correction, enter the following command to set the offset angle to zero:

ØFE

After ØFE has been executed the OFFSET light will be turned off indicating that auto-alignment is no longer active.

6-5. DESCRIPTION OF THE TWO AXIS AUTO-ALIGNMENT CAPABILITY OF THE MODELS MPP-1 AND MPP-2

The Models MPP-1 and MPP-2 provide three additional two axis auto-alignment features beyond those of the Model MPP.

First, the Model MPP-1 and MPP-2 measure offset angles up to 360 degrees whereas the Model MPP measures an offset angle no larger than 90 degrees. This 360 degree capability allows the operator greater flexibility in positioning workpieces on the Cordax machine.

Second, whereas the Model MPP is capable of auto-alignment only in the XY plane, the Models MPP-1 and MPP-2 perform two axis auto alignment in any of the three working planes. The desired working plane is chosen by entering the Select Active Plane command before measuring the offset angle. After this command is executed, the appropriate ACTIVE PLANE light in the upper right of the display will be lit to indicate which plane was chosen for the alignment procedure.

Finally, the Models MPP-1 and MPP-2 allow the operator to modify, set or display the offset angle as necessitated by the measuring task. Setting the offset angle to any value from 0 to 360 degrees is accomplished with the Set Offset Angle command which is entered in the following format:

DEGREES/FE (e.g.: 216FE)

This command is most commonly used to cancel the offset angle compensation by using the value of zero, as follows:

ØFE

The Display Offset Angle command may be used to have a stored offset angle appear on the top row of the display for the temporary display interval. It is entered as follows:

FD

The Modify Offset Angle command is used when measuring the offset angle is difficult or impractical, as is the case with the workpiece illustrated in figure 6-5. This asymmetrically shaped part is shown as viewed from the top, against the XY plane and in this case the edge of the part along which the two points (labeled A and B) will be recorded for measuring the offset angle is not the workpiece X axis, nor is the part edge parallel to the part X axis. Therefore, measuring points A and B will render an inaccurate angle for alignment purposes.

The offset angle (labeled 1 in figure 6-5) in this type of case, can be obtained by summing the angle measured (labeled 2) and the supplementary angle (labeled 3) which is formed by the workpiece edge and the workpiece X axis. This is done with the Modify Offset Angle command. For this example, if the size of the supplementary angle is known, for instance from a part print, the offset angle would be determined in three steps:

1. Record two points along the workpiece edge (points A and B in figure 6-5).

2. Enter the Calculate and Store Offset Angle command (FØE or FE).

3. Enter the size, in degrees, of the supplementary angle, followed by the Modify Offset Angle command. In this case, the command would be:

-18F1E

An angle is considered to be positive if it is measured clockwise from the part axis, and it is considered to be negative if it is measured counterclockwise from the part axis.

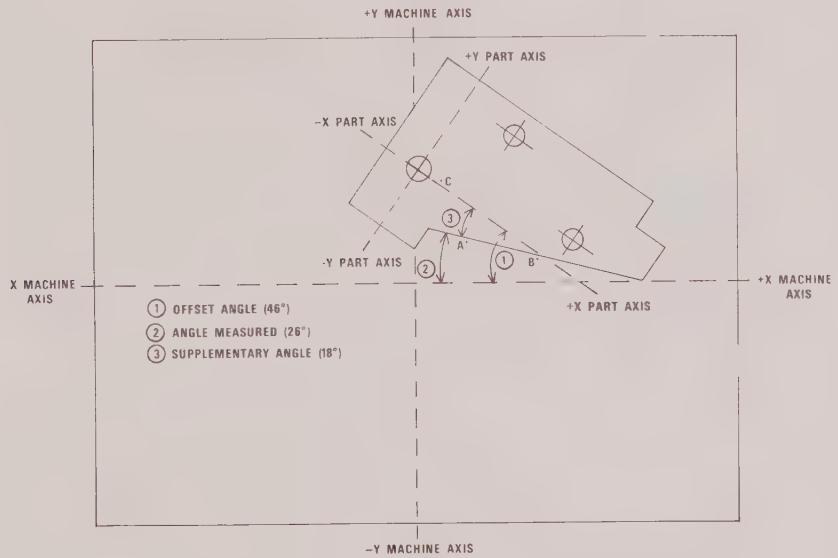


Figure 6-5. Asymmetrical Part Against XY Plane Showing Angles to be Measured for XY Plane Alignment

If the size of the supplementary angle is not known, it can be defined, in terms of axis coordinates, not in degrees of angle. To do this, after the two points have been recorded and the Calculate and Store Offset Angle command has been entered, the operator may use a part print to determine the coordinates of a point along the part axis. For example, point C in figure 6-5 is located at the coordinates +X9 and +Y2. These coordinates can be used for measuring the supplementary angle by entering them into the Modify Offset Angle command, in the following format:

AXIS LETTER/COORDINATE/AXIS LETTER/COORDINATE/F1E

In the figure 6-5 example, the command would be:

X9Y2F1E

The axes must be entered in the order they are named in the active plane; i.e., in this case, the active plane is XY and so the coordinates are entered X before Y.

6-5.1 Summary of Steps in Performing Active Plane Auto-Alignment with the Models MPP-1 and MPP-2

1. Align the workpiece and machine axes which are perpendicular to the active plane.

2. Enter the Select Active Plane command in one of the following forms:

Command	Description
F3E or XYF3E	Selects the XY plane
XZF3E	Selects the XZ plane
YZF3E	Selects the YZ plane

3. Record with the measuring probe two points:

a. along the positive end of the part axis corresponding to the first named axis in the active plane, or

b. along a line parallel to the positive end of the part axis corresponding to the first named axis in the active plane, or

c. if the Modify Offset Angle command is to be used, the two points should be recorded along the line which forms the supplementary angle.

d. for any of the steps a, b or c, the second point recorded must be at a more positive location along the axis than the first point.

4. Enter the Calculate and Store Offset Angle command by pressing the keypads:

FØE or FE

FE may be used instead of FØE because whenever the MPP encounters an F without a following number it assumes the F to mean the same as FØ.

5. If the Modify Offset Angle command is to be used, enter it giving the size of the supplementary angle in degrees, if the supplementary angle size is known. For example:

-20F1E

Remember: an angle is positive if it is measured counterclockwise from the machine axis; if the angle is measured clockwise from the machine axis, it is negative.

If the supplementary angle size is not known, enter the Modify Offset Angle command using axes coordinates from a point along the line which forms the supplementary angle, for example:

X10Y5F1E

6-6. DESCRIPTION OF THE THREE AXIS AUTO ALIGNMENT CAPABILITY OF THE MODEL MPP-2

The Models MPP and MPP-1 provide the capability to align a part to two axes, i.e., one plane, after it has been manually aligned to the third axis. The Model MPP-2 has this, and an additional capability which, when the two capabilities are used together, allows auto-alignment to all three axes.

Normally, if features of a workpiece to be measured are located on an oblique part face, the operator would use step blocks or other fixturing devices to position the workpiece so that the oblique face would be parallel to one of the measurement planes. With the MPP-2, such a part would still need to be clamped to the worktable so that it would not be inadvertantly moved during the measurement process, but it would not be necessary to fixture the workpiece so that the oblique part face is physically parallel to one of the measurement planes. The Model MPP-2 can mathematically rotate a part face or plane so that it is parallel to any one of the three active planes.

For example, shown in figure 6-6 is a part with an oblique (inclined) face on which measurements must be made. As shown, the oblique part face is not parallel to any of the measuring machine working planes. With the MPP-2, rather than having to prop or fixture the part to make the inclined face parallel to a machine plane, the operator could simply record three points on the oblique face, enter two commands, and for the remainder of the measurement process the MPP-2 will execute and maintain mathematical compensations so that measurements recorded and displayed will appear as if the oblique face were parallel to a machine plane.

Figures 6-7 through 6-9 show three ways which the MPP could align the oblique part plane to a measurement plane. In Figure 6-7, the oblique part face has been made level, or parallel to the XY plane represented by the Cordax vertical arm machine table top. This is the most likely rotation for the part shown. However, the Model MPP-2 could rotate the oblique part face so that it would be parallel to the XZ plane, as illustrated in figure 6-8, or rotate it parallel to the YZ plane as pictured in figure 6-9. How the part is rotated is dependent upon the part shape and the measuring task. In the process of planning the measuring procedure, it must be kept in mind that the part features to be measured must be accessible to the measuring probe and that the part axes should be defined according to the rotation desired.

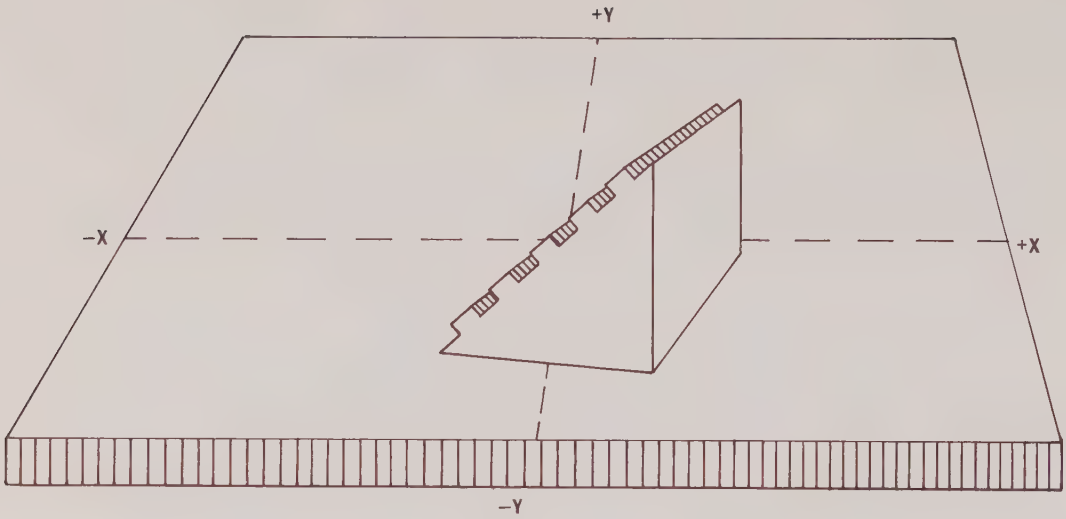


Figure 6-6. Workpiece with an Oblique Face

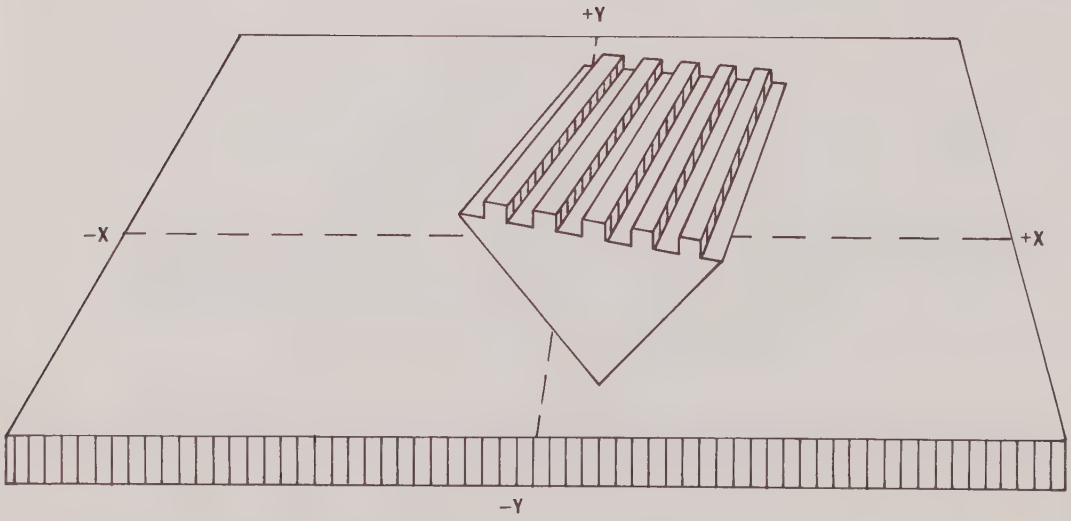


Figure 6-7. Oblique Workpiece Face Mathematically Rotated Parallel to XY Plane

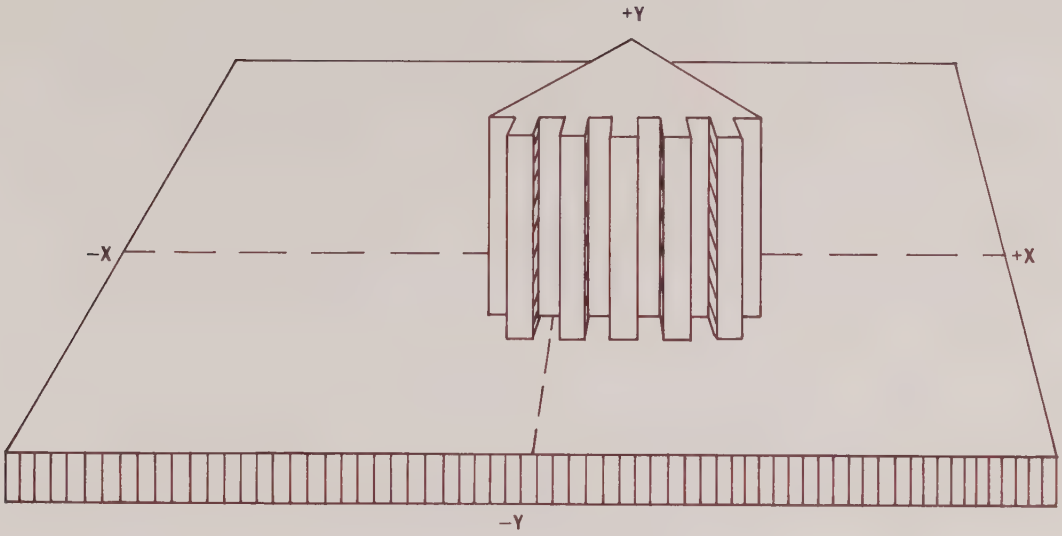


Figure 6-8. Oblique Workpiece Face Mathematically Rotated Parallel to XZ Plane

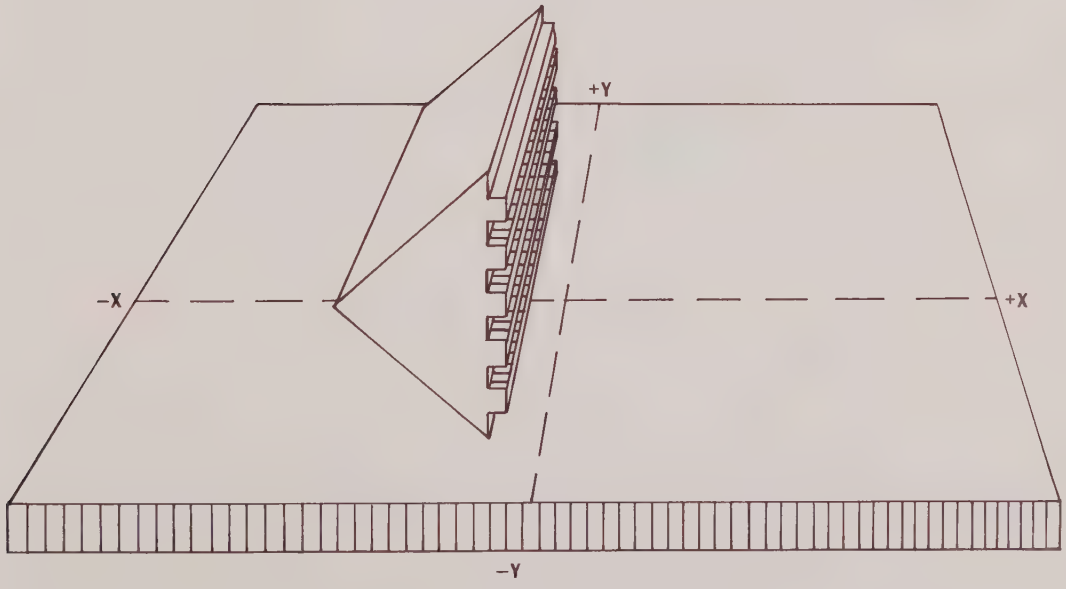


Figure 6-9. Oblique Workpiece Face Mathematically Rotated Parallel to YZ Plane

Figure 6-10 illustrates the way in which the part axes were defined for the rotation which is shown in figure 6-7 (oblique face made parallel to the XY plane). In this instance, what has happened as a result of the oblique face rotation is that the Z-part and Z machine axes have been aligned, as illustrated in figure 6-11. However, when the part is envisioned in its rotated position and is viewed from the top, as it appears in figure 6-12, it may be seen that the X and Y part axes remain to be aligned with the machine X and Y axes. This alignment is accomplished, as described in section 6-5, by measuring and storing the offset angle. It should be noted that when the Model MPP-2 part rotation feature is utilized, the Plane Rotation command must always precede the offset angle measurement.

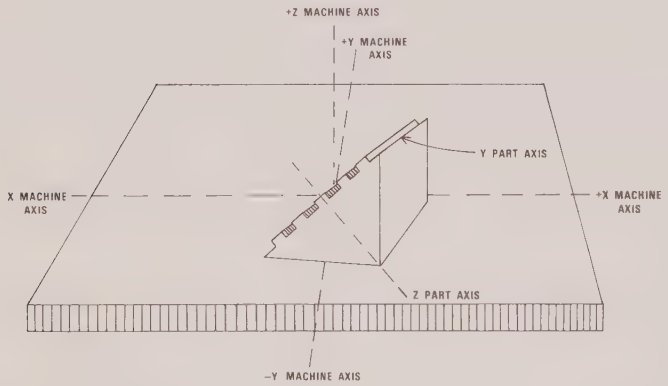


Figure 6-10. Illustration of Workpiece Axes for a Part with an Oblique Face

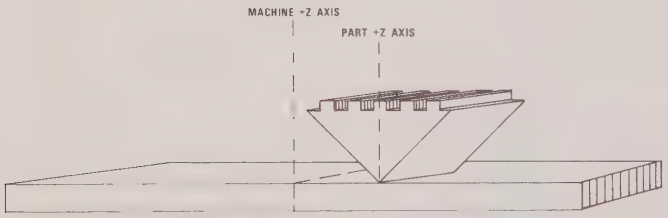


Figure 6-11. Illustration of the Way the Z Machine and Part Axes Pictured in Figure 6-10 Appear after the MPP-2 Has Mathematically Rotated the Oblique Part Face Parallel to the XY Plane

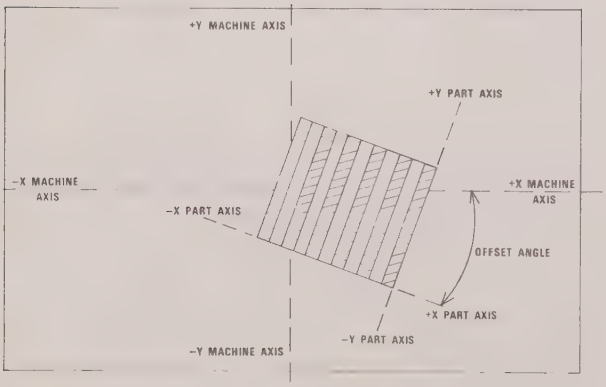


Figure 6-12. Top view of Part Shown in Figure 6-10

6-6.1 Summary of Steps in Performing Three Axis Auto-Alignment with the Model MPP-2

1. Position the workpiece such that the part features to be measured are accessible to the measuring probe.

2. Enter the Select Active Plane command in one of the following forms:

Command	Description
F3E or XYF3E	Selects the XY plane
XZF3E	Selects the XZ plane
YZF3E	Selects the YZ plane

The active plane selection identifies the machine plane to which the measured plane is to be parallel after rotation. For example, in figure 6-7, the oblique part face was rotated parallel to the XY plane and so, in that instance, the XY plane was selected as the Active Plane. For the rotations in figures 6-8 and 6-9, the XZ and XZ planes, respectively, were the Active Planes.

3. Record with the measuring probe three points on the part plane to be rotated. The three points measured define the part plane which will be rotated parallel to the Active Plane selected in step 2. No particular order or pattern for these three points is required, but it is best to measure them as far apart as possible and to try to avoid measuring them on burrs, in pits, etc. For example, on the part illustrated in figures 6-6 through 6-12, the three points would be recorded all on top of the ridges shown or all at the base of the grooves.

4. Enter the Plane Rotation command in the following format:

n or -nF23E or F23E (e.g.: -3F23E)

The **n** value indicates one of the three machine axes, as follows:

Value of n	Machine Axis
1 or -1	X
2 or -2	Y
3 or -3	Z

The n value which precedes the F23E command describes to the MPP-2 the physical relationship, before rotation, of the machine axes and the part plane which will be rotated. This is necessary because after the active plane selection and part plane definition, as described in steps 2 and 3, there are two ways which the MPP-2 could rotate the part plane and the n value indicates to the MPP-2 which rotation the operator desires. Specifically, the n value identifies an end of a machine axis which points in the general direction of the positive surface of the part plane to the rotated.

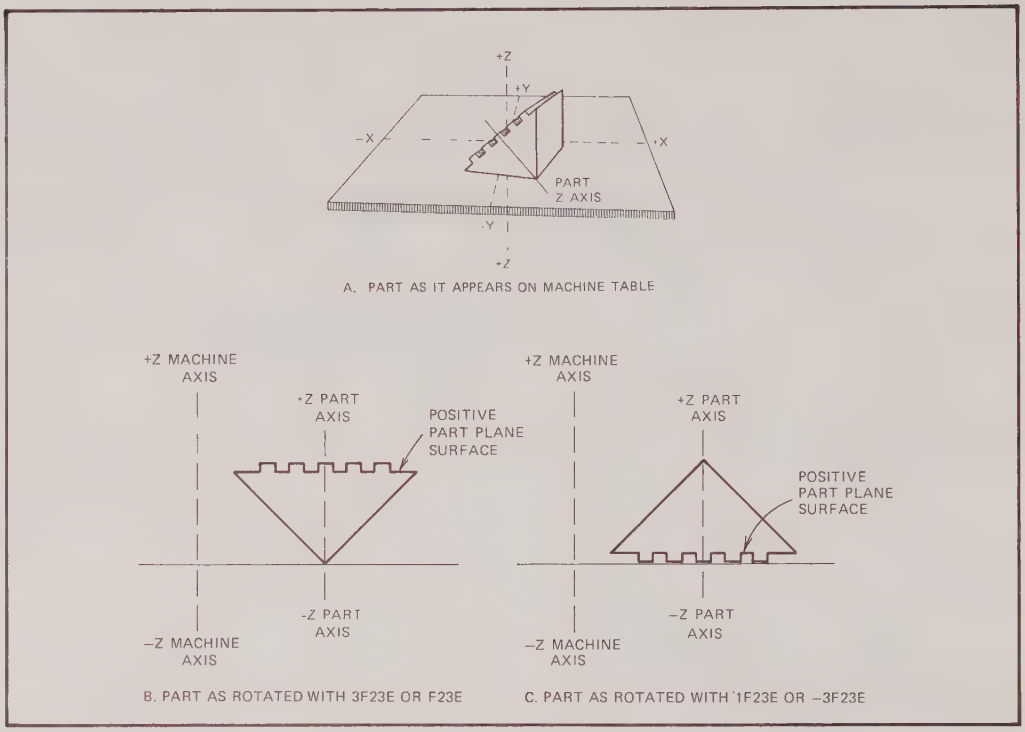


Figure 6-13. Illustration of Function 23

To understand the use of the n value, it is necessary to envision the part as it sets on the machine table and as it will appear to the MPP-2 after rotation has taken place. Figure 6-13A shows a part as it sets on the machine table. For this example, the active plane is the XY plane and the three points recorded in step 3 are located on the inclined, grooved face of the part.

Figure 6-13B shows the same part as it would be mathematically rotated using either of the following commands:

3F23E or F23E

In this case, the n value of 3 indicates to the MPP-2 that the +Z-axis as shown in figure 6-13A is generally pointing in the direction of the surface of the part plane to be rotated which will be positive after rotation has taken place. For such a rotation, the n value is optional and may be omitted from the command. The n value may be omitted any time it identifies the positive end of the axis which is perpendicular to the active plane because this indicates the most common type of plane rotation and is the rotation to which the MPP-2 will default.

Figure 6-13C shows the part as it would be rotated using either of the following commands:

1F23E or -3F23E

In the first instance, the n value of 1 indicates that the +X axis as shown in figure 6-13A is generally pointing through the part in the direction of the surface of the part plane which will be positive after rotation. In the second instance, the -3 n value gives the same indication, i.e., the -Z axis as shown in figure 6-13A points generally in the direction of the part plane surface which will be positive after the rotation.

5. Calculate and store the offset angle as described in section 6-5.

6-7. PROBE REORIENTATION FOR THE MODELS MPP-1 AND MPP-2

If it is planned, at any point during the measurement process, to change the probe attitude (i.e., to change the direction from which the probe tip approaches the workpiece by using a device such as a right angle adaptor) or to change from one probe to another, a Probe Reorientation command must be executed before the part alignment procedure is begun.

The purpose of the Probe Reorientation command is to provide a convenient way of reestablishing a part reference point (described in section 7) after a probe attitude change or probe exchange. For the Model MPP-1, the Probe Reorientation command can be executed only for rigid probes. For the Model MPP-2, probe reorientation may be executed for a rigid probe or an Omniprobe.

6-7.1 Models MPP-1 and MPP-2 Rigid Probe Reorientation

The two steps of Rigid Probe Reorientation are described in terms of a ball tip probe and a cone-shaped reference fixture although the principle applies to other types of rigid probes and reference fixtures as well.

First, set up a reference fixture on the measuring machine worktable as illustrated in figure 6-14. The reference fixture must remain in place throughout the measuring process; therefore, it must be located where it will not interfere with part measurement. For ball tip probes, a cone-shaped fixture which screws into the worktable is available from Bendix. Next, place the ball tip probe in the cone fixture and enter the following Probe Reorientation command:

F20E

The footswitch should not be pressed. The Probe Reorientation command causes the displayed reading to change but does not necessarily set the display to zero.

Proceed with the normal steps required to measure the part (alignment, establishing a datum reference point, and measurements). Immediately after each probe replacement or attitude change, place the probe tip in the reference fixture and enter the Probe Reorientation Command (F20E).

This operation will compensate for probe change with no effect on part datum, part alignment, scaling or previously recorded points.

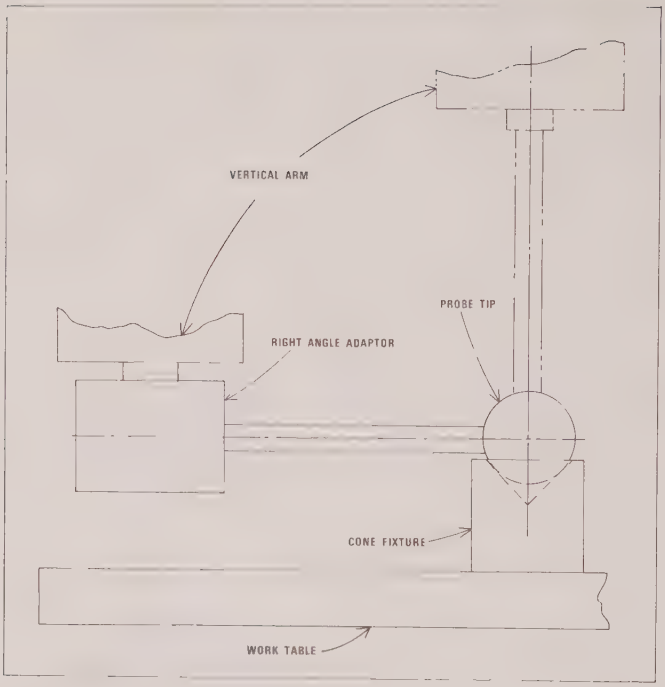


Figure 6-14. 90-Degree Rigid Probe Reorientation Using a Right Angle Adaptor

6-7.2 Model MPP-2 Omniprobe Reorientation

The Omniprobe reorientation procedure requires the operator to measure the XYZ center coordinates of a reference sphere before starting measurement operations and during the measurement process after each probe tip change or reorientation. To do this, first, mount a spherical reference ball firmly onto the measuring machine worktable where it will not interfere with the planned measurement task, then enter the following Omniprobe Reorientation command:

F27E

After the command is entered, the MPP displays the number 4 in the W-axis row of the display and the OFFSET light begins flashing. Use the footswitch to record four widely spaced measurements on the reference sphere (see figure 6-15), for example three around the center (equator) and one on top (north pole). The rule governing the recording of points on the sphere is: the first three points recorded will define a plane passing through the sphere and the fourth point recorded must be at some location which does not lie in that plane. As the footswitch is pressed to record each of the four measurements, the number shown in the W-axis row of the display is reduced by one indicating the number of measurements remaining to be made on the sphere. After the fourth measurement, the OFFSET light stops flashing and the X, Y, and Z displays return to probe tracking, indicating that the operation is complete.

Proceed now with all the desired measurement operations. Immediately after each probe exchange or attitude change, enter the Omniprobe Reorientation command and measure the four points on the reference sphere. This operation will compensate for probe change with no effect on part datum, alignment, scaling or previously recorded points.

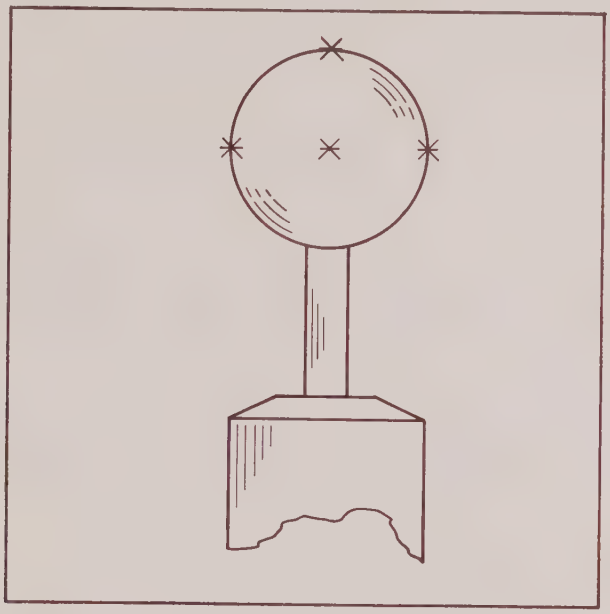


Figure 6-15. Illustration of Possible Measurements for Omniprobe Reorientation

SECTION 7. ESTABLISHING WORKPIECE REFERENCE POINTS AND CHANGING AXIS SCALE FACTORS

When power is turned on to the MPP, the zero point on each of the axes is located at the point where the probe tip is resting. This point can be anywhere within the probe travel range along the X, Y and Z axes. The Cordax system is designed in this manner because the first step in the measurement process, after part alignment, is to move the axes zero point to a specified location on the workpiece to be measured. Creating a zero reference point on a part allows all measurements to be added or subtracted from zero.

To determine where the zero reference point of a workpiece should be located, if it is not indicated on a part print, refer to section 6-2.

For all MPP models, the basic methods of establishing a datum reference point are resetting or presetting the axis displays. In addition, Models MPP-1 and MPP-2 offer three reference datum establishing functions which will be described after the reset and preset methods.

Normally, when the measuring probe is moved one inch or millimeter, the axis displays reflect that inch or millimeter of movement. The MPP provides the capability of altering that one to one scale factor for special applications such as measuring scale models and this procedure is described in the final paragraphs of this section.

7-1. RESETTING AND PRESETTING THE AXIS DISPLAY

The four axis reset keypads are used to set the rows of the display to zero. These keypads may be used to establish a reference datum by contacting the chosen datum point with a probe and pressing the reset keypads corresponding to the rows of the display being reset. If using an Omniprobe, the zero reset occurs at the location where the probe tip is initially deflected and not necessarily at the probe tip location where the reset keypad is pressed. When using a rigid probe, the datum point is recorded from the probe centerpoint. Anytime a reset operation is executed a single beep will be sounded. Under certain operating conditions, the MPP will temporarily refuse to execute a reset operation. When this occurs, a series of beeps will be sounded. In this instance, wait a moment and press the keypad again.

In instances where the desired datum reference point is not accessible to the measuring probe, the datum point may be established by presetting the axes displays. For example, in figure 7-1 it is assumed that datum point A is not accessible but datum point B can be contacted with the measuring probe. The distances along the X and Y axes between datum A and datum B are known from a part print to be X350 and Y200. In this instance the zero reference point could be established at datum A by contacting datum B with the probe and presetting the X and Y rows of the display to 350 and 200 respectively. (In this case, datum A and datum B exist in the same plane so that the Z axis row of the display could simply be reset to zero.)

The basic preset command has the following format:

AXIS LETTER/COORDINATE/ENTER

More than one axis may be preset in a command; for example, the command for the two axes in figure 7-1 would be:

X350Y200E

Lead zeros to the left of a decimal point and trailing zeros to the right of it are not required. A decimal point is unnecessary for whole numbers. To store the preset command, it is necessary only to press the keypads while the probe is contacting the workpiece; do not press the footswitch. Before entering a preset command, check to ensure that the MM/INCH switch is set to the same type of measurement unit to be entered.

When measuring a series of identical parts, the preset command may be abbreviated after it has been fully entered a first time, leaving out the coordinate values and entering only the axis letter(s) and ENTER. For example, if a series of parts such as that pictured in figure 7-1 were to be measured, the preset command for the first part would be entered as X350Y200E, then when a second, identical part has been aligned for measurement, it is necessary only to contact the part at datum B and enter XYE.

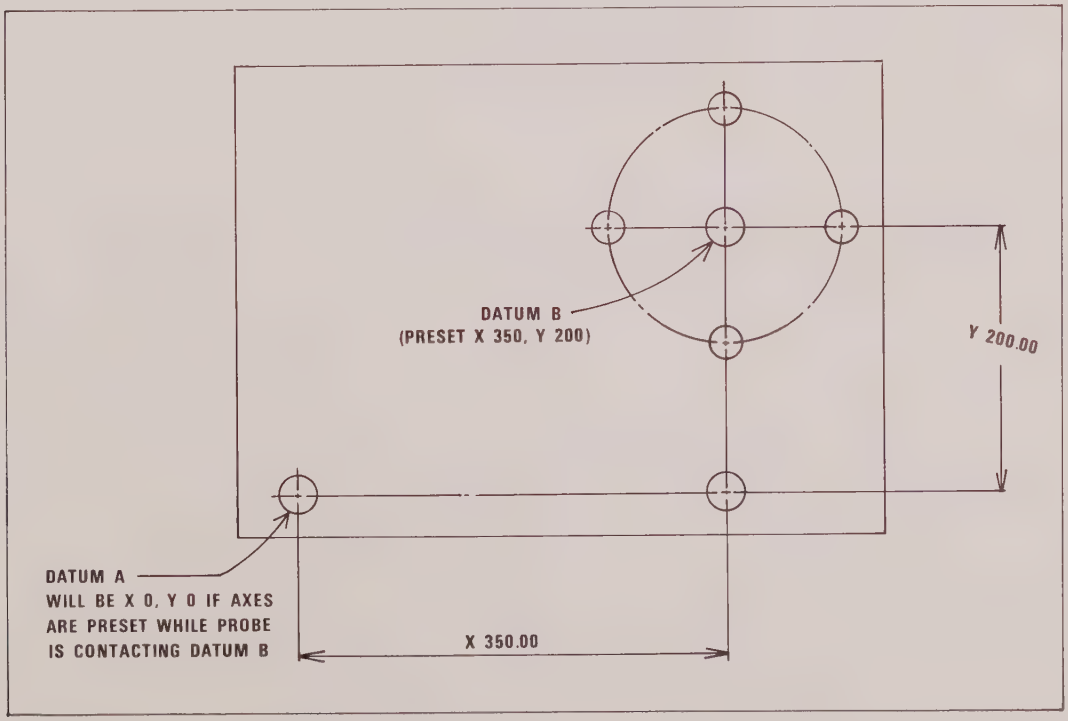


Figure 7-1. Presetting the Axes to Establish a Zero Reference Datum

7-2. MODELS MPP-1 AND MPP-2 DATUM ESTABLISHING COMMANDS

The three datum establishing functions exclusive to the Models MPP-1 and MPP-2 are Function 4, Set Datum to Last Recorded Point; Function 5, Save Datum; and Function 6, Recall Datum.

The Set Datum to Last Recorded Point function is useful in many instances, one of which is establishing the reference datum as the center of a large I.D. or O.D. which cannot be measured in any way other than by executing the three point centerfind procedure (described in section 8). In such a case, once the three-point centerfind procedure is done, the center of the I.D. or O.D. is the last point recorded. To set the datum to that point, a command in the following format would be entered:

AXIS LETTER/AXIS LETTER/F4E (e.g.: XYF4E)

After the MPP-1 or MPP-2 has executed the command, it sets the specified axes to zero at the location of the last recorded point.

The Save and Recall Datum functions, used in conjunction with a form of the Function 4 command, are useful in cases where engineering drawings are dimensioned with more than one datum point. For such parts it may be convenient to establish an initial datum, measure features referenced to this datum, save the initial datum, establish (or move) the datum to a new location, measure features in reference to the new datum and then recall the initial datum for further use. After an initial datum point has been established, such a sequence of events is accomplished by first, entering a Save Datum command in the following format:

AXIS LETTER(s)/F5E (e.g.: XYF5E)
or
F5E

This command stores the current datum points for the axis or axes named so that they may be recalled later. If no axis letters precede the command, the datums for all three axes are saved.

Next, the second datum point is established by using any of the previously described datum establishing methods, or by using a move datum command, the format of which is:

AXIS LETTER/MINUS SIGN IF NECESSARY/DISTANCE/F4E

For example, to move the datum 5 units (inches or millimeters) in a positive direction along the X-axis, this command would appear as follows:

X5F4E

Two or more axis datum points may be moved in a single command. For example, a command moving the datum for X, 5 positive units and the Y-datum 4 negative units would appear as follows:

X5Y-4F4E

Negative signs are required for indicating distances in a negative direction along an axis; plus signs are not required for indicating distances in a positive direction.

To recall the initial datum point, which was stored with the Save Datum command, a Recall Datum command must be executed. Entering the Recall Datum command in the following format:

F6E

will recall the datum point for all three axes. If it is desired to recall the datum point(s) for one or two axes but not all three, the Recall Datum command has the following format:

AXIS LETTER(s)/F6E (e.g.: XYF6E)

If the Recall Datum command is entered and no datum points were previously stored, the recalled datum points will be zero or some erroneous numbers.

7-3. CHANGING THE SCALE FACTOR OF THE MODELS MPP-1 AND MPP-2

The Cordax system is designed so that when the measuring probe is moved one unit (inch or millimeter) along an axis, the corresponding row of the display reflects one unit of movement. This one to one ratio (1:1) of probe movement to displayed value is the normal Cordax system scale factor. For certain measurement procedures it may be convenient to change that scale factor, as in the case of measuring a model of a part which is smaller or larger than the normal part size. In such a case, it would likely be efficient for the display to reflect not the actual distances measured by the probe on the model but rather the measurements as they would appear if the normal sized part were being measured. This can be accomplished with one of two Change Scale Factor commands.

With, for example, a half scale model, one unit of measured distance on the model is the equivalent of two units of distance on a full sized part. This means that the ratio of probe movement to displayed value would be 2:1 if it were set to reflect measurements on a normal sized part. The MPP reads scale factors as the first number of the ratio. In other words, the normal scale factor is 1.000, corresponding to the 1:1 ratio. In the case of the 2:1 ratio, the MPP would read the scale factor as 2.000.

In the case of a model which is twice as large as a normal workpiece, one unit of measured distance on the model is the equivalent of one-half a unit of distance on a normal sized part. In this case the ratio of probe movement to displayed value is 1/2:1. If the first number of a ratio is less than 1.0 it is expressed as a decimal fraction, i.e., 1/2:1 is entered as .5.

The command for changing the scale factors of all linear axes simultaneously utilizes Function 2 and has the following format:

SCALE FACTOR/F2E

For example, if the scale factor is 2.000 this command would appear as follows:

2F2E

Lead zeros to the left of a decimal point and trailing zeros to the right are unnecessary. If the scale factor is .5, this command would appear as .5F2E.

If it is desired to change the scale factor on one or two of the axes but not all three axes simultaneously, then a second form of the Function 2 command is used which has the following format:

AXIS LETTER/SCALE FACTOR/F2E

For example, if the scale factor of the X and Y axes was to be changed to .65, the command would appear as follows:

X.65Y.65F2E

At any time during the measuring process, the current scale factors may be temporarily displayed by entering the command:

F2D

When this command is executed, the auxiliary data lights to the left of the display will come on and each row of the display will show a scale factor. This display will last for the temporary display interval, then the auxiliary data lights will go out and the display will revert to showing the probe position coordinates.

To return all axes to a scale factor of 1.000 after they have been reset, enter the command F2E. To return one or more axes to a 1.000 scale factor, enter the command in the following format:

AXIS LETTER(s)/1/F2E

7-3.1 Reversing the Signs of the Axes

In addition to changing scale factors, the Function 2 may also be used to reverse the sign of one or more of the axes. For example, normally the right side of the X-axis is positive and left side is negative. To reverse the axis signs so that the opposite is true, without changing the scale factor, the following command could be entered:

X-1F2E

Or, to change the scale factor to 2:1 and reverse the signs of all the axes, the Function 2 Command could be entered as follows:

-2F2E

To cancel the axis sign reversal for all axes and to reset the scale factor to 1.000, enter the command:

F2E

To cancel the axis sign reversal for one or more axes and reset the scale factor to 1.000, enter the command in the following format:

AXIS LETTER(s)/1/F2E

To cancel the sign reversal for one axis and reset the scale factor to a value other than 1.000, enter the command in the following format:

AXIS LETTER/POSITIVE SCALE FACTOR/F2E

SECTION 8. MEASUREMENT CAPABILITIES

All models of the MPP measure straight line distances, simply by tracking the probe as it is moved from one point to another. The distance is calculated by noting the reading on the axis display at each end of the distance traveled by the probe and subtracting the first reading from the second reading. Or, if the axis is reset to zero before the probe is moved along the distance to be measured, the display reading when the probe stops moving is the distance between the two points.

By itself, the Model MPP is used basically to measure straight line distance and does not have other, such as circular measurement, capabilities. The Models MPP-1 and MPP-2 have circular feature measurement capabilities which utilize the principle that three points in a plane mathematically describe a circle of specific size and center location. With the Model MPP-1 a circular feature, or a circle formed by circular features (e.g., a bolt hole circle) may be measured using a procedure called the Three-Point Centerfind method. The Model MPP-2 has not only the Three-Point Centerfind capability but also two other circular measurement features called the Multi-Point and Scanning Methods. All three methods, described in this section, calculate the centerpoint and diameter of a circle.

8-1. USING THE MODELS MPP-1 AND MPP-2 THREE-POINT CENTERFIND METHOD FOR CIRCULAR FEATURE MEASUREMENT

There are four steps in performing the Three-Point Centerfind method: selecting the active plane, entering the probe diameter, measuring three points on the circular feature and entering the command to calculate the centerpoint and diameter.

Before measuring a circle, the active plane must be selected, i.e., the MPP must be informed of the plane in which the circle lies because the center coordinates of the feature are calculated in relation to the two axes of that plane. Any of the machine working planes may be selected, and once the selection has been made, it will be indicated by the appropriate front panel ACTIVE PLANE light being lit. Selecting an active plane for circular feature measurement does not cancel or in any way alter a previously performed part alignment procedure.

The Select Active Plane command for circular feature measurement is entered in one of the following ways:

Command	Description
XYF3E or F3E	Select XY Plane
XZF3E	Select XZ Plane
YZF3E	Select YZ Plane

The next step in the Three Point Centerfind procedure is entering the diameter of the probe tip which will be used to record three points on the circular feature. (This is necessary because the true diameter of an I.D. is the measured diameter plus the probe diameter and the true diameter of an O.D. is the measured diameter minus the probe diameter). To allow the MPP to compensate for probe diameter during calculations, enter the probe diameter using the following command:

PROBE DIAMETER/F9E (e.g.: .5F9E)

The probe diameter must always be a positive number in the measurement unit currently selected with the MM/INCH switch.

The third step in the procedure is recording with the probe three points on the circular feature being measured. To do this, contact the part with the probe and press the footswitch, move the probe to a second location on the circular feature, press the footswitch, move the probe again and press the footswitch the final time.

To calculate the centerpoint and diameter from the just recorded points, enter the appropriate one of the two following commands:

F7E (if an I.D. is being measured)
F8E (if an O.D. is being measured)

After the command is executed, the MPP will display the active plane center point coordinates of the circle in the appropriate rows of the display. For example, if the XY plane was selected as the active plane, the circle centerpoint coordinates will appear on the X and Y rows of the display. The diameter of the circle will appear on the W-axis row of the display (If the diameter is too large for display, the W-axis row of the display will be blank). While the circular feature data are displayed the AUX DATA lights will be lit. After the temporary display interval has elapsed, the display will revert to showing the normal probe position coordinates and the AUX DATA lights will go out. The three points recorded with the probe will be erased from the MPP memory but the centerpoint and diameter of the circular feature will remain in the memory as the last recorded point.

To display the centerpoint and diameter of the just measured circular feature after the temporary display interval has ended, enter either one of the following commands:

F7D
F8D

The F7D and F8D commands only recall for display the last recorded point. Therefore, the centerfind data cannot be recalled and displayed after a subsequent measurement has been recorded.

8-2. USING THE MODEL MPP-2 MULTI-POINT METHOD FOR CIRCULAR FEATURE MEASUREMENT

When measuring a circular feature with a rough surface finish using the Three-Point Centerfind method, if any of the three recorded points is located on a burr or in a pit, the centerpoint and diameter calculations may not be as precise as needed. If, however, the calculations for a rough surfaced I.D. or O.D. are made from more than three recorded points, the accuracy of the calculations can be increased. It is for this reason that the MPP-2 offers a Multi-Point method for measuring circular features.

The Multi-Point procedure is very similar to the Three-Point Centerfind method. The differences are that the operator sets the number of points to be recorded and then records that number of points.

To execute the Multi-Point procedure, enter the active plane and probe diameter as described for the Three-Point Centerfind method, then enter the Multi-Point command for an I.D. or an O.D., indicating the number of points to be measured, as follows:

#F24E (for an I.D., e.g.: 6F24E)
#F25E (for an O.D., e.g.: 12F25E)

The number of points to be measured must be three or more. The general rule is that the rougher the surface of the circle to be measured, the larger the number of points which should be recorded. After the command is entered, the number of points will appear in the W-axis row of the display, and the OFFSET light will begin flashing, signaling that the MPP is waiting for points to be recorded. It will continue to flash until all the points have been recorded. As each point is recorded, the number in the W-axis row of the display will decrease by one, signaling the number of remaining points to be recorded.

After the last point has been recorded, the coordinates of the circle centerpoint will appear in the appropriate rows of the display and the diameter of the circular feature will appear in the W-axis row of the display. This data will remain on the display for the temporary display interval.

To display the centerpoint coordinates and diameter of the just measured circle after the temporary display interval has ended, enter either one of the two following commands:

F7D
F8D

The F7D and F8D commands only recall for display the last recorded point. Therefore, the centerpoint and diameter cannot be recalled after a subsequent measurement has been recorded.

8-3. USING THE MODEL MPP-2 SCANNING METHOD FOR CIRCULAR FEATURE MEASUREMENT

The Scanning method is performed only with vertical arm Cordax machines using a rigid probe.

To execute the Scanning procedure, enter the active plane and probe diameter as described for the Three-Point Centerfind method, then enter the Scanning command for an I.D. or an O.D., as follows:

F24E (for an I.D.)
F25E (for an O.D.)

Next place the rigid probe tip at a starting point on the I.D. or O.D., press and release the footswitch. The operation of the footswitch causes the display to become blank, the OFFSET light to begin flashing (signaling that the MPP is waiting for measurements) and the MPP to begin recording measurements at the rate of eight per second. Move the probe slowly and steadily around the circular feature, keeping it firmly in contact with the part feature surface at all times. When the probe has been moved around the entire circumference of the circle, press the footswitch to stop the data recording process.

After the footswitch is pressed at the end of the scan, the active plane center coordinates and the average third axis reading will appear in the appropriate rows of the display and the diameter of the circular feature will appear in the W-axis row of the display. The data will remain on the display for the temporary display interval.

To display the centerpoint coordinates and diameter of the just measured circle after the temporary display interval has ended, enter either one of the two following commands:

F7D
F8D

The F7D and F8D commands only recall for display the last recorded point. Therefore, the centerpoint and diameter cannot be displayed after a subsequent measurement has been recorded.

8-4. USING THE MODELS MPP-1 AND MPP-2 TO MEASURE A CIRCLE FORMED BY THREE CIRCULAR FEATURES

The center point and diameter of a circle formed by three circular part features (such as bolt holes or bosses) can be measured using a variation of the Three-Point Centerfind procedure which contains three steps.

First, each of the circular features which form the circle are individually measured using the Three-Point Centerfind method. As illustrated in figure 8-1, the operator would measure the bolt holes labeled A, B, and C.

Next, the probe diameter is set to zero with the following command:

ØF9E

Finally, the Three-Point Centerfind command for the circle formed by the circular features is entered. Either of the following commands may be used:

F7E
F8E

After the F7E or F8E command is executed, the centerpoint coordinates will appear in the appropriate rows of the display and the diameter of the circle will appear in the W-axis row of the display, for the temporary display interval. After the temporary display interval ends but before subsequent measurements are recorded, the centerpoint and diameter data may be recalled for display by entering either of the following commands:

F7D
F8D

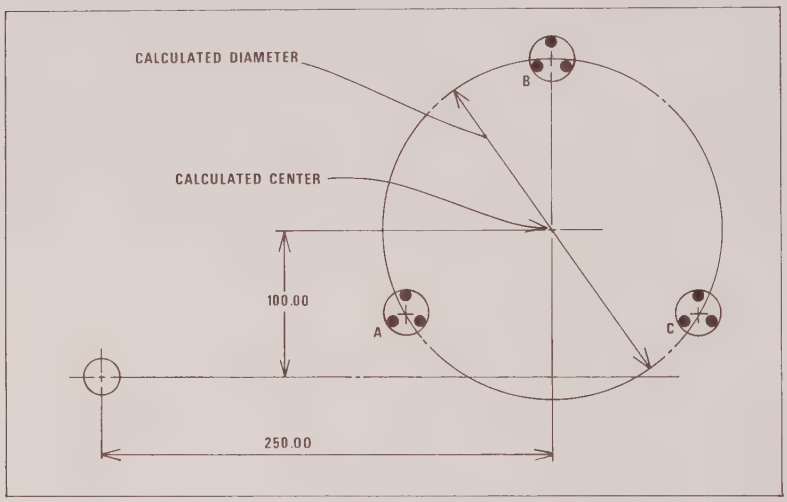


Figure 8-1. Measuring a Circle Formed by Three Circular Features

8-5. USING THE MODEL MPP-2 TO MEASURE A CIRCLE FORMED BY A VARIABLE NUMBER OF CIRCULAR FEATURES

When it is desired to measure a circle formed by more than three circular features, a variation of the Model MPP-2 Multi-Point method must be used which allows the operator to set the number of circular features which will be measured.

To measure such a circle, enter the following command preceded by the number (#) of circular features which will be measured:

#F26E (e.g.: 6F26E)

After the command has been executed, the number entered before the command will appear on the W-axis row of the display and the OFFSET light will begin flashing, signaling that the MPP is waiting for measurements to be recorded.

Next, record with the probe and footswitch, three points on each circular feature. As each circular feature is measured the active plane centerpoint coordinates will be shown in the appropriate rows of the display and the diameter will appear in the W-axis row of the display for the temporary display interval. After the temporary display interval has ended the X, Y, and Z rows of the display will revert to normal probe tracking and the number of circular features yet to be measured will appear in the X-axis row of the display.

After the last circular feature is measured and its center and diameter are displayed, the MPP computes and displays, for the temporary display interval, the active plane coordinates of the center point and the diameter of the circle formed by the circular features. After the temporary display interval ends but before subsequent measurements are recorded, the centerpoint and diameter of the circle may be recalled for display by entering either of the following commands:

F7D
F8D

SECTION 9. CONVERSION TO POLAR MODE USING THE MODELS MPP-1 AND MPP-2

By issuing a single command the operator can cause the currently selected active plane linear coordinates to be converted to polar form so that measurements may be made as radii and angles rather than linear distances (as described in section 1).

To convert from linear to polar coordinates, the following command is entered:

F10E

After the command is executed, the MPP will show constantly updated polar coordinates of the radius in the display row corresponding to the first named active plane axis and the angle will be shown in the display row corresponding to the second named active plane axis. For example, if the active plane is XZ, the radius will appear in the X-row and the angle in the Z-row of the display. The third linear axis (not named in the active plane) is not affected by the polar conversion and continues to display linear coordinates. The AUX DATA lights will be lit for the active plane axis rows of the display so long as the polar conversion is in effect.

When polar conversion takes place, any previous offset angle and scale factor compensations remain in effect and the radii are reflected in inches or millimeters according to the current setting of the MM/INCH switch. It should be noted that negative scale factors (see section 7) or reversal of the count reversal switches (see section 13) will affect the sign of the displayed angle.

In polar mode, the displayed radius is the straight line distance from the currently stored part reference datum to the probe position. The displayed angle is measured counterclockwise from the first named active plane axis, as illustrated in figure 9-1.

To cancel polar mode and return to linear coordinate mode, enter the command:

F11E

After this command is executed the AUX DATA lights will go out and the display will revert to tracking the probe along the linear axes.

It should be noted that if the RESET keypads are used while in polar mode, they will respond as if they were zeroing the linear coordinates, resulting in correspondingly changed polar mode numbers on the display.

The axis preset operation also deals only in linear coordinates. To preset values for polar display, the values must be entered as linear coordinates of the active plane axes before the Polar Conversion Command is entered.

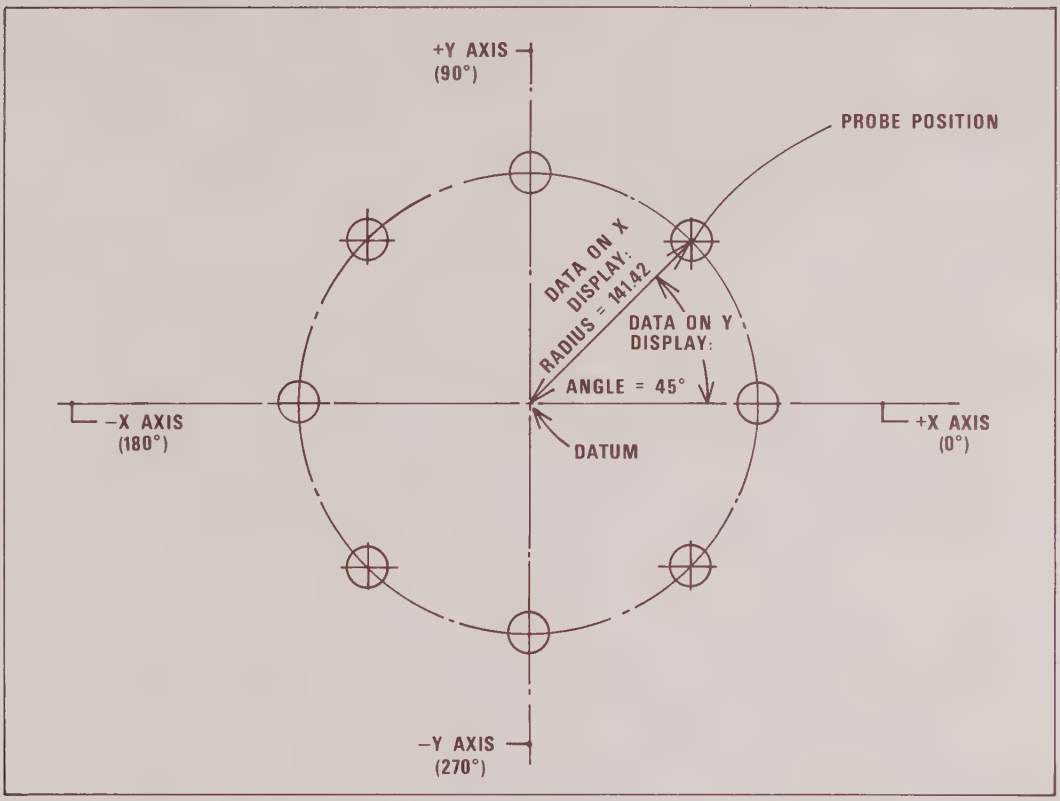


Figure 9-1. Illustration of Polar Mode

SECTION 10. ENTERING AND DISPLAYING INSPECTION DATA WITH THE MODELS MPP-1 AND MPP-2

The entry and output of inspection data using the MPP has been structured in such a way that only two commands need be used to obtain any combination of actual, nominal, tolerance, deviation, and out-of-tolerance information for the linear or rotary axes or polar mode capabilities of the MPP. Information needed for the data portion of these commands is given in table 10-1 on the following page.

The first thing to note about table 10-1 is that it has six columns, labeled, across the top: 1. Actual, 2. Nominal, 3. Plus Tol, 4. Minus Tol, 5. Dev and 6. Out of Tol; and eight rows, labeled, from top to bottom: 1. X-axis coordinate, 2. Y-axis coordinate, 3. Z-axis coordinate, 4. W-axis coordinate, 5. Diameter, 6. Radius, 7. Angle and 8. True Position. A row number and a column number are used together in a Data Entry command to represent one of 45 different types of inspection data.

For example, to store nominal and tolerance data for the diameter of a circular feature which is to be measured while the Cordax system is in the linear (not polar) mode, look at the intersection of columns 2, 3, and 4 labeled Nominal, Plus Tol and Minus Tol and Row 5, labeled Diameter. As illustrated in figure 10-1, at the intersection of Column 2 and Row 5 is the number 2.5; for Column 3 and Row 5 is the number 3.5 and for Column 4 and Row 5 is the number 4.5. These numbers are entered into a Data Entry command which has the following format:

C#C#C#.R#R#R#F50E

In this case, C# means column number and R# means row number. The column and row numbers are separated by a decimal point. The information from the table for this example may be entered in the command as follows:

234.5F50E

Row \ Column	1 Actual	2 Nominal	3 Plus Tol	4 Minus Tol	5 Dev	6 Out of Tol
1 X-axis Coordinate	1.1	2.1 (XN)	3.1 (XP)	4.1 (XM)	5.1	6.1
2 Y-axis Coordinate	1.2	2.2 (YN)	3.2 (YP)	4.2 (YM)	5.2	6.2
3 Z-axis Coordinate	1.3	2.3 (ZN)	3.3 (ZP)	4.3 (ZM)	5.3	6.3
4 W- axis Coordinate	1.4	2.4 (WN)	3.4 (WP)	4.4 (WM)	5.4	6.4
5 Diameter	1.5	2.5 (DN)	3.5 (DP)	4.5 (DM)	5.5	6.5
6 Radius	1.6	2.6 (RN)	3.6 (RP)	4.6 (RM)	5.6	6.6
7 Angle	1.7	2.7 (AN)	3.7 (AP)	4.7 (AM)	5.7	6.7
8 True Position			3.8 (TP)		5.8	6.8

Figure 10-1. Example of How to Read Table 10-1

Table 10-1. Variable Elements for Data Entry and Data Display Commands

Row \ Column		1 Actual	2 Nominal	3 Plus Tol	4 Minus Tol	5 Dev	6 Out of Tol
1	X-axis Coordinate	1.1	2.1 (XN)	3.1 (XP)	4.1 (XM)	5.1	6.1
2	Y-axis Coordinate	1.2	2.2 (YN)	3.2 (YP)	4.2 (YM)	5.2	6.2
3	Z-axis Coordinate	1.3	2.3 (ZN)	3.3 (ZP)	4.3 (ZM)	5.3	6.3
4	W- axis Coordinate	1.4	2.4 (WN)	3.4 (WP)	4.4 (ZM)	5.4	6.4
5	Diameter	1.5	2.5 (DN)	3.5 (DP)	4.5 (DM)	5.5	6.5
6	Radius	1.6	2.6 (RN)	3.6 (RP)	4.6 (RM)	5.6	6.6
7	Angle	1.7	2.7 (AN)	3.7 (AP)	4.7 (AM)	5.7	6.7
8	True Position			3.8 (TP)		5.8	6.8

Legend:

Column 1: Actual represents an actual measurement, either straight line or angular, as recorded from a workpiece. The actual measurement is compared to the nominal measurement to obtain deviations from nominal and out-of-tolerance values.

Column 2: Nominal is a desired straight line or angular measurement, usually taken from an engineering drawing.

Column 3: Plus Tolerance is the amount, in a positive direction along an axis, by which an actual measurement is allowed to vary from a nominal measurement.

Column 4: Minus Tolerance is the amount, in a negative direction along an axis, by which an actual measurement is allowed to vary from a nominal measurement.

Column 5: Deviation is the difference between the actual measurement and the nominal measurement, i.e.,

Deviation = Actual - Nominal

Table 10-1. Variable Elements for Data Entry and Data Display Commands (cont.)

The deviation is positive if the actual measurement is more positive than the nominal measurement; the deviation is negative if the actual measurement is more negative than the nominal measurement.

Column 6: Out-of-Tolerance is the amount by which the actual measurement falls outside the tolerance range for a straight line or an angle, i.e.,

Out of Tolerance = Deviation - Tolerance

For plus and minus tolerancing, if the deviation is negative, the MPP compares the deviation to the minus tolerance; if the deviation is positive, the MPP compares the deviation to the plus tolerance.

Rows 1-4: X, Y, Z, and W Axes Coordinates are the four axes of the measuring system. The W-axis is usually the rotary table angular measurement axis.

Row 5: Diameter refers to the diameter of a circle calculated by a circular feature measurement command.

Rows 6 and 7: Radius and Angle are the polar coordinate equivalents of the active plane linear coordinates.

Row 8: True Position represents "regardless of feature size" positional tolerancing and the circular tolerance zone. (For further reference, see Dimensioning and Tolerancing, ANSI Y14.5 published by the American Society of Mechanical Engineers).

Entering 234.5F50E informs the MPP that the operator is waiting to store in memory a nominal value, and a plus and minus tolerance for the diameter to be measured. The MPP responds by prompting the operator for those values, one at a time. In other words, after the 234.5F50E command is entered, the MPP responds first, by showing, in the X-axis row of the display, the numbers 2.5 which correspond to Column 2 (Nominal), Row 5 (Diameter) from table 10-1. The operator responds by entering the nominal diameter and then presses the ENTER keypad. Next the MPP shows 3.5, prompting the operator to enter the plus tolerance for the diameter. After the operator has entered that value and pressed the ENTER key, the MPP displays 4.5, prompting the operator to enter the minus tolerance for the diameter. After the final value has been entered, the MPP reverts to showing the probe position coordinates on the display.

The 234.5F50E example command illustrates that it is not necessary to repeat identical column or row numbers in a command. In other words, 234.5F50E should not be entered as 234.555F50E; if it were entered with 234.555, the MPP would prompt the operator three times for the nominal and tolerance information. Likewise, if the operator desires to enter a single nominal for an X, a Y, and a Z coordinate, the command would be entered as 2.123F50E, not 222.123F50E.

Columns 2, 3, and 4 are the only ones for which data may be entered in a Data Entry Command. It is not necessary to enter the column and row numbers in ascending order (as they were in the previous example). For example, the column/row pairs C4R3, C3R6, C3R7 may be entered in ascending order (42.367F50E) or in other combinations such as 24.673F50E. If no column and row numbers are present in a Data Entry command (i.e., only F50E is entered) the MPP applies the last entered format for accepting new nominal and tolerance data for the current measurement. If no such format has been stored since the last power interruption, the display will be blank for an instant after the F50E is entered, then it returns to normal coordinate display.

If an error is made while entering the command or responding to an MPP prompt for nominal or tolerance data, press the CLEAR keypad which deletes all information entered since the previous depression of the ENTER keypad and reenter the command or data.

After a Data Entry command is entered a Data Display command may be used to display elements from table 10-1 which relate to the Data Entry command. For example, if a nominal and a tolerance value for a diameter were entered using a Data Entry command, after the diameter was measured a Data Display command could be entered to display not only the stored nominal and tolerance and the actual diameter measurement, but also the computed deviation and out-of-tolerance values for the diameter. Like the Data Entry command, the Data Display command uses column and row numbers from table 10-1, as follows:

C#C#C#.R#R#R#F60E

Any number of column/row pairs of numbers may be entered in a Data Display command, but only the first four are displayed. The values are shown for the temporary display interval, from the top to bottom row of the display in the order specified in the command. For example, in the case of the command: 156.5F60E, the following would appear on the display:

X-axis display row:	Actual Diameter Measurement
Y-axis display row:	Diameter Deviation from Nominal
Z-axis display row:	Amount Diameter is Out-of-Tolerance

The following rules which pertain to the Data Display command should be noted:

1. Actual (Column 1) values are the coordinates of the last recorded point. If no point has been recorded since turning on the MPP, an error message will be displayed. The actual value always reflects the state of the MM/INCH switch, offset angle, part reference, and scale factors.

2. Nominal (Column 2), Plus Tolerance (Column 3) and Minus Tolerance (Column 4) values are always displayed exactly as entered.

3. Deviation (Column 5) and Out-of-Tolerance (Column 6) values are always in the measurement unit currently set by the MM/INCH switch.

4. No output is available for undefined true position values (Nominals, Plus and Minus Tolerances, Actuals).

5. If there was no input for a specified data element, zeroes will be displayed.

6. An error message is displayed when values are not available for computation. For example, when Deviation and Out-Of-Tolerance values are requested and no point has been recorded since power was turned on, an error message will be displayed.

7. The data will be displayed using the same format (i.e. decimal point location) as is currently in use for coordinate displays. If a value cannot be displayed using that format because it has too many digits to the left of the decimal point, an error message will be displayed.

10-1. CONVERTING NOMINAL DATA FROM LINEAR TO POLAR COORDINATES AND VICE VERSA

Active plane coordinates may be entered in linear mode and then converted to polar coordinates by executing the Data Entry command as previously described, and then entering the following Nominal-Polar Conversion command:

F17E

To convert active plane nominal polar coordinates to linear coordinates, the following Nominal-Linear Conversion command is used:

F16E

These commands are useful if, for example, a part print indicates nominal data in one coordinate form, but the operator desires to make measurements in the other mode. For instance, figure 10-2A and B shows a portion of a part print representing a workpiece with three bolt holes which must be measured in relation to the bore in the lower left corner. Assuming the operator has the part print shown in figure 10-2A where nominal linear coordinates are given for the bolt holes, but it is desired to make the measurements in polar mode, the operator would enter the linear nominal data using the following Data Entry Command:

2.12F50E

This command would cause the MPP to prompt the operator to enter the X-axis linear nominal coordinate (14) and then to enter the Y-axis linear nominal coordinate (12). To convert those linear nominal coordinates to polar nominals, the operator would then enter the F17E command. When F17E is executed the MPP will calculate the distance between the 0 datum point and linear point X14, Y12 and store this distance as the polar mode radius. Next, the MPP will calculate the degrees of angle between the positive end of the first named axis of the active plane and the just-calculated radius, and store this angle in memory. The radius and angle are then the stored polar mode nominals for the nominal linear coordinates X14, Y12.

Executing F17E does not cause the linear nominals to be erased from the MPP memory, it merely adds a set of polar nominals to the memory, and likewise, executing F16E would not cause the originally stored polar nominals to be erased from memory. Therefore, either the polar or linear nominals could be recalled for display with the Data Display command. In this example, the Data Display command 2.12F60E would cause the linear nominal coordinates X14 and Y12 to be displayed. Or if the Data Display command 2.67F60E were entered, it would cause the R4.8 and A45 nominals to be displayed.

It should be noted that nominal conversion can take place only in the current active plane, and the appropriate Select Active Plane command should be executed, if necessary, before F16 or F17 is used.

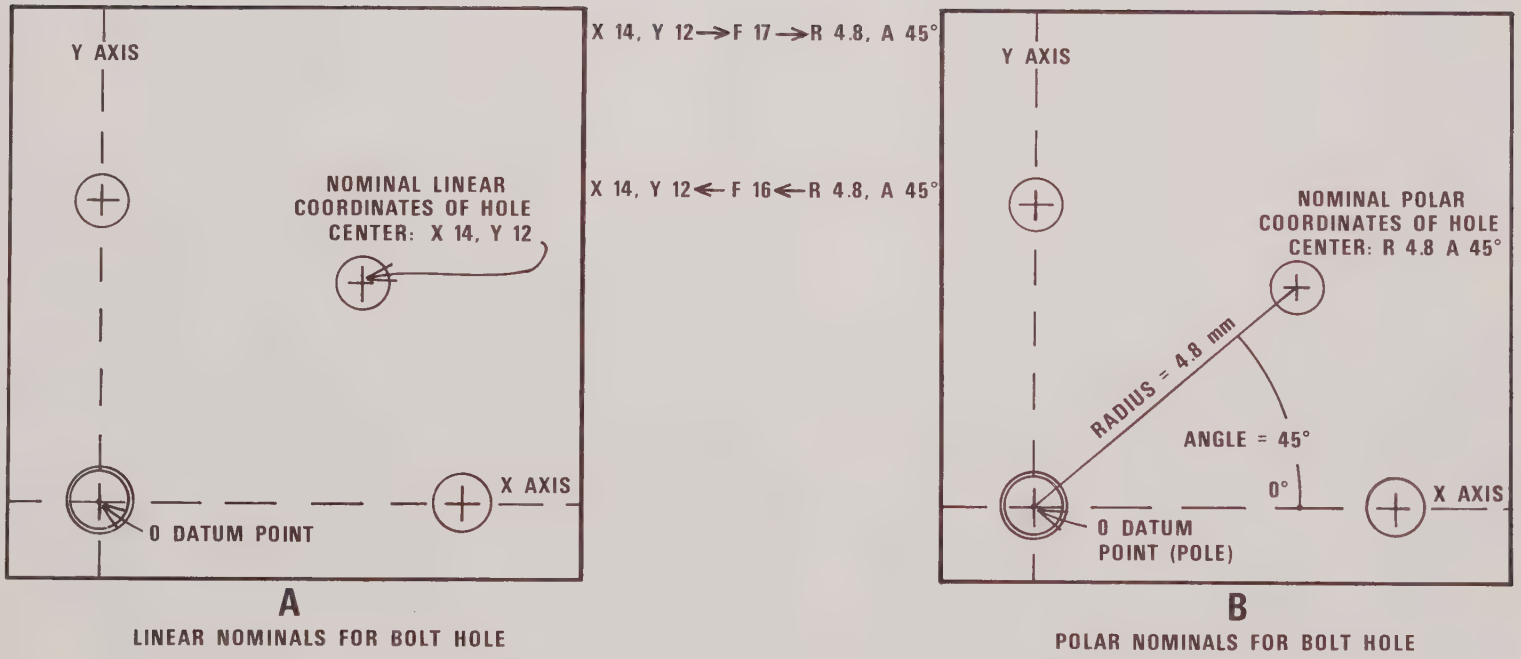


Figure 10-2. Illustration of Linear-Polar Nominal Conversion

SECTION 11. STORING AND REPEATING COMMAND SEQUENCES WITH THE MODELS MPP-1 AND MPP-2

The Models MPP-1 and MPP-2 have the capability to store and then execute a sequence of commands comprised of up to 200 keypad operations. This stored command loop may be repeated indefinitely, a specified number of times or until interrupted by the operator, and it will remain stored in the MPP until power is interrupted or until a new command loop is entered. This repetition of a sequence of commands is particularly useful in applications where the same set of operations is required to measure a series of similar workpieces.

In addition to the commands described in preceding and following chapters, there are a set of "miscellaneous" commands which are especially helpful in writing a command loop. They will be described here, followed by instructions for composing and storing a command loop.

11-1. SET THE TEMPORARY DISPLAY INTERVAL COMMAND

The display normally shows continuously updated probe location coordinates, but this function is interrupted to show auxiliary data which results from measurement commands or operator entered commands to recall and display stored data. Measurement results and other auxiliary data which interrupt the showing of probe location coordinates normally appear on the display for a 5 second time period. This temporary display interval may be shortened or lengthened by using the following command:

SECONDS/F13E (e.g.: 30F13E)

The maximum number of seconds which may be entered in the command is 4,095. The minimum temporary display interval is Ø second; when the interval is set to zero the auxiliary data will flash once on the display for a split second. The appropriate axis auxiliary data lights are lit during the temporary display interval. Once the F13 command has been entered, the newly set display interval will remain stored in the MPP until a second F13 command is entered or until power is interrupted.

To display the temporary display interval setting, the following command is entered:

F13D

After the command is executed, the number of seconds to which the display interval is set appears in the X-axis row of the display.

11-2. DISPLAY RECORDED POINT COMMAND

When a point is recorded by pressing the footswitch, its coordinates are stored in a "stack" in the MPP memory. The stack can contain up to six recorded points which are numbered one through six; the most recently recorded point has the lowest number in the stack, (i.e., 1), and the oldest point in the stack has the highest number, i.e., if the stack is full, the oldest point is 6. If a point is recorded when the stack is already full, the oldest point (i.e., 6), will be dropped, all other points will move up one in number and the newest point will become number 1.

Any of the six points stored in the stack may be recalled for display by entering the following command:

#F18D (e.g.: 3F18D)

The number entered at the beginning of the command indicates which of the points in the stack will be displayed; 3F18D recalls point 3 from the stack. If no number is entered at the beginning of the command (i.e. F18D is entered) the most recently recorded point will be displayed.

The AUX DATA lights will be lit while the recalled coordinates are being displayed. The display will be maintained for the temporary display interval and it will reflect the current setting of the MM/INCH switch, part reference, offset angle, axis scale factors and polar/linear mode.

11-3. DELETE RECORDED POINT COMMAND

The following command will erase the most recently recorded point from the the memory stack:

F19E

After the command is executed the remaining points in the stack will be renumbered; i.e., when F19E is entered, point 2 becomes point 1, etc. through point 6.

11-4. WAIT FOR MEASUREMENT(S) COMMAND

When building a command loop it is sometimes convenient to have the MPP prompt the operator to record a certain number of points before the next step in the loop is executed. This may be done with the Wait For Measurement command which is entered as follows:

#F15E (e.g.: 2F15E)

The number which precedes the function is the number of points which must be recorded before the MPP will go on to the next step in the command loop. Only the numbers 1, 2, or 3 may precede the command, or, if no number precedes the command the MPP reacts as if the number 1 had been entered.

After the Wait for Measurement(s) command is executed, the OFFSET light begins flashing, signaling the operator that the MPP is waiting for the programmed number of points to be recorded. Until the designated number of points are recorded, the MPP will not process any other commands.

11-5. DISABLE AND ENABLE FOOTSWITCH COMMANDS

Normally, the footswitch is always active and ready for recording points. However, when executing a command loop it is important that the points to be recorded are taken in the proper sequence and at the proper time. To prevent accidental data recording, the Disable Footswitch command may be written into a command loop so that data recording occurs only on command (for example, after a Wait for Measurement command has been executed). The Disable Footswitch command is entered as follows:

F21E

To counteract the Disable Footswitch command and return the footswitch to the normally active mode, the following Enable Footswitch command is entered:

F22E

11-6. COMPOSING AND STORING A COMMAND LOOP

Before attempting to enter a command loop it is advisable to carefully plan the steps in the measurement procedure and to write out the commands in proper form and sequence.

The first command in any loop must be the Build Loop command. It must be entered before the first command in the sequence and it may not appear any where else in the loop. It is entered as follows:

#F14E (e.g.: 6F14E)

The number which precedes F14 indicates the number of times the loop is to be executed. The maximum number of allowable executions is 32,767. If no number precedes F14, the loop will be repeated indefinitely, until power is interrupted (which will erase the loop) or until the operator manually aborts the loop execution.

Once the Build Loop command has been executed the MPP is ready to accept the command sequence. All keypad operations except axis resets and the F14, F40, and F41 may be entered in the loop. The commands in the loop will not be executed as they are entered.

If a mistake is made while entering commands with the keypads, pressing the CLEAR keypad will delete all characters entered after the last operation of the ENTER or DISPLAY keypads. Syntax errors, beyond initial character filtering, will not cause an error message to be displayed during the entry of the command sequence (if syntax or other errors are present, error messages will be displayed during the first execution of the loop, and the loop will be aborted).

Any attempt to enter more than 200 characters (a character is one depression of a keypad) will cause an error message to be displayed and the loop aborted. When the operator has entered 160 characters the MPP will show, for the temporary display interval, the remaining number of allowable characters after each command has been entered.

Starting command loop execution is achieved by a single or double depression of the ENTER keypad after all commands have been entered. The ENTER keypad is pressed twice if the last command in the loop ended with a D (DISPLAY), otherwise, the ENTER keypad need be pressed only once. After starting, the loop will be repeatedly executed until the number of executions specified in Build Loop command is exhausted, until an error is detected, until the power is interrupted or until the operator manually ends execution.

The operator may stop execution of the loop at any time by pressing the X keypad. When this is done, a series of beeps will sound. If the loop was interrupted while executing a Display command (a command which ends with a D),

pressing the X-keypad will cause the loop to stop after the temporary display interval. If the X-keypad is pressed during execution of a Data Entry (F50) command, the loop will terminate only after all data items are entered. If the X-keypad is pressed while the loop is executing or waiting to execute other commands, execution of the loop will cease immediately.

After a loop has been manually interrupted by the operator or after the number of executions entered in the Build Loop command has been reached, the operator may restart the loop, providing the power has not been interrupted. To restart the loop execution, the following command is entered:

#F14D (e.g.: 5F14D)

As with the Build Loop command, the number which precedes F14 designates the number of times the loop will be executed, and if the number is omitted and only F14D is entered the loop will be repeated indefinitely until interrupted.

Following is an example of a command loop as it might be used to measure a circular feature.

Command	Explanation
5F14E	Build loop command, set to execute loop five times.
XYF3E	Select XY active plane.
2F15E	Wait to measure two points for offset angle.
FE	Compute offset angle.
.5F9E	Enter probe diameter.
3F15E	Wait to measure three points for centerfind.
F7E	Compute ID center and diameter.
E	Execute loop.

SECTION 12. USING THE MODEL MPP-2 WITH A PERIPHERAL INPUT/OUTPUT DEVICE

When a peripheral input/output (I/O) device is used in conjunction with the Model MPP-2, the operator may enter commands and data through the I/O device or through the MPP front panel keypads. In addition, an I/O device provides the capability of printing MPP input and output and storing part programs (e.g., command loops) in some permanent fashion, such as on a paper tape.

The I/O device selected for use with a Model MPP-2 depends upon the intended application. A typical device which will be referred to in this chapter is the Teletype® Model ASR-33 which consists of a typewriter-like keyboard and printer, a paper tape reader and paper tape punch. This chapter describes how to use the Teletype keyboard for data and command input, how to use the printer to output measurement results and how to utilize paper tapes for part programming.

12-1. ENTERING COMMANDS WITH THE TELETYPE KEYBOARD

When power is turned on to the system, control of the MPP lies in the front panel keypads. To route control from the keypads to the Teletype so that commands and data may be typed on the keyboard, set the Teletype control knob in the ON position (or on some machines to LINE position) and enter the following command via the MPP front panel:

F41D

When this command is executed, only the MPP axis reset keypads, the X keypad (used for exiting a command loop), and the CLEAR keypad will be operative. So long as F41D is in effect, all data and commands must be entered via the Teletype.

After the F41D command has been executed, every time a character key on the Teletype is pressed, that character will be printed. In computer terminology, this printing of characters is called echoing. It is possible, although not recommended when entering data or commands, to turn off the echo (printer). This is accomplished by entering the following command:

F41E

This command may be used instead of F41D or any time after F41D has been executed and it is desired to turn off the echo.

To route MPP control from the Teletype back to the MPP keypads, the following command is entered:

F40E

It should be noted that when using the Teletype to enter command, anytime a command is terminated with a D (DISPLAY), that terminator should be typed and if the operator desires to advance the paper to the next line, the RETURN and LINE FEED keys should be pressed. Whenever a command is terminated with an E, the E key should

not be pressed. On the Teletype, pressing the RETURN key takes the place of pressing the ENTER keypad on the MPP. For example, to enter the command F41D, the operator would type each of the four characters, then to advance the paper, press the RETURN key, but when entering the F41E command, the operator could type only F41 and then press the RETURN key, which will cause the MPP-2 to generate the RETURN/LINE FEED sequence. Also, it should be noted that the C key on the Teletype keyboard functions in the same way as the MPP CLEAR keypad.

12-2. EXECUTING DATA ENTRY AND DATA DISPLAY COMMANDS USING THE TELETYPE

All commands described in this manual have the same format when entered through the MPP keypads or the Teletype; however, the Data Entry and Data Display commands provide an exception to the rules set forth in section 12-1 and require further explanation when used with the Teletype.

The exception to the rules governing F41 is this: when input control of the MPP has been routed to the Teletype using F41, it is still possible to enter nominal and tolerance data via the MPP keypads. This feature may be useful when measuring a series of similar but not identical workpieces. For example, if the inspection tasks for measuring six workpieces are identical except that each workpiece has a unique set of nominal and tolerance data, all of the functions required to execute the measurement procedure, excluding the nominal and tolerance data, could be punched into a paper tape. The taped program could be started for the first workpiece and when the point in the procedure is reached where the nominal and tolerance data must be entered for the first part, the operator would use the MPP keypads to enter the nominal and tolerance data. (In such a case, if nominal and tolerance data have not been punched into the tape, they must be entered via the MPP keypads and not via the Teletype.) This sequence of events could then be repeated for the remaining five similar workpieces.

When it is desired to enter nominal and/or tolerance data from the MPP keypads even though F41 is in effect, the Data Entry command is entered in the same manner described in Section 10, using F50. When it is desired to enter a Data Entry command from the Teletype keyboard, F51 is used. A Data Entry command using F50 is always terminated with an E, but when F51 is used, the command may be ended with a E or a D depending upon the prompting desired. With F51 when the Teletype Data Entry command is terminated with a D, both the MPP display and the Teletype printer will prompt the operator to enter the specified nominals and/or tolerances. The MPP display will show the column and row numbers from table 10-1, and the Teletype will print the letters shown in parentheses beneath the column and row data in columns 2 through 4 of the table. For example, if the following command is entered on the Teletype:

3.2F51D

The MPP display will show the following prompt:

3.2

and the Teletype printer will type the prompt:

YP=

In this case, the operator would respond by entering the plus tolerance for the Y-axis through the Teletype.

If the Teletype Data Entry command is terminated with an E (ENTER), for example 3.2F51E, the command will be executed in the same manner as the 3.2F51D command but only the MPP will prompt the operator to enter the specified data. Use of this version of the Teletype Data Entry command is recommended only when preparing a paper tape (as described in section 12.5).

The Teletype Data Entry commands, like their keypad counterpart, may be entered without specifying column and row data. This causes the MPP to prompt the operator for the same nominals and/or tolerances specified in the previous Data Entry command.

When using the Teletype, inspection data is printed rather than displayed on the MPP. This is accomplished by using one command to print column headings which correspond to those in table 10-1, and a second command to print the data.

To print headings, the following command is entered:

C#C#C#.R#R#R#F71E

C# represents the number of the column for which a heading will be printed. R# represents the row number of data which will be printed later when an F61E Print Data command is entered. Any or all of the six column headings may appear, in any order in the command. For example, 5.56F71E causes the following headings to be printed:

DEV OTOL

To print inspection data under the column headings after the 5.56F71E command was entered, one of two commands could be entered:

5.56F61E
or
F61E

If the column and row designations are omitted, as is the case with the F61E above, the last entered PRINT/DISPLAY DATA column and row designations are recalled and used for the current command. If any data value for an F61 command is too large to be printed, a series of asterisks will be printed in its place.

The printout for the 5.56F71E command, followed by the 5.56F61E or F61E commands would appear as follows:

```
        DEV      OTOL
#0001
D       0.4000   0.0100
```

The #0001 is the sequence number which is described in the following section. A sequence number will be typed above each set of printing unless the Print Data command is preceded by a minus sign. For example, the printout for the following command would not have a sequence number printed above it:

-5.56F61E

12-3. THE SEQUENCE NUMBER

The sequence number is always present in a digital counter in the MPP and it may be used by the operator for identifying steps in a command loop, or when the Teletype Print Data command is executed, it automatically numbers the sets of printing unless suppressed as described in section 12-2.

The sequence number is always set at zero when the power to the MPP is turned on. It may be set to any whole number ranging from -9,999 to +9,999 by executing the following Set Sequence Number command where # represents the value to which the sequence number will be set:

#F12E

It is frequently useful to set the sequence number when composing a command loop. The most common use of the command is to set the sequence number from its initial zero state to one. This could be done by entering the command one of two ways:

1F12E
or
F12E

Anytime F12E is entered without a preceding number, the sequence number is incremented (raised) by one.

To display the sequence number on the X-axis row of the display, the following command is entered:

F12D

Following is an example of how the Set Sequence Number command might be used in a command loop:

Command	Explanation
1F12E	Set the sequence number to one.
5F14E	Start command loop and execute it five times.
F21E	Disable footswitch.
F12D	Display the sequence number.
F12E	Increment sequence number by one.
2F15E	Wait for two points to be recorded before executing further commands. In this case the operator would record two points for calculating the offset angle.
FE	Compute offset angle.
3F15E	Wait for three points to be recorded, in this case for executing the Three-Point Centerfind command.

Command	Explanation
F7E	Three-point centerfind calculates center coordinates and diameter of an ID.
E	Start loop execution.

12-4. COMMENTS

The operator may type comments on the Teletype output without interfering with the entry or execution of commands. When a comment is desired between commands, the operator types an asterisk (*) at end of the command but before RETURN, followed by the comment of any length and then presses the RETURN key. The asterisk signals the MPP to ignore all characters entered after the asterisk and until the RETURN key is pressed. A comment may also be started on a line by itself. The only restriction on comments is that they may not be entered in the midst of a command.

Comments are frequently useful for making notes during the measurement process or, in the case of using paper tapes, for reminding the operator when and how specific points should be recorded.

12-5. PART PROGRAMMING WITH PAPER TAPES

A part program is very similar to the previously described command loop; it is a sequence of commands and data used to achieve a specific end, such as inspecting features of a workpiece. A part program may be carried out using the MPP keypads or the Teletype keyboard by themselves, or by storing the program steps or commands on a paper tape. The paper tape, once correctly punched, has the advantage or allowing the operator to merely place the tape in the reader at the beginning of the measurement procedure, rather than having to type in each command of a series everytime the same procedure is to be performed.

All of the commands which are used in a command loop (see section 11) may be punched into a paper tape. Comments may also appear in a tape and may be especially useful for reminding the operator to take measurements when the loop reaches Wait for Measurement command, or in similar instances.

12-5.1 Example of Part Programming Using a Paper Tape

This section describes how to use the Teletype reader and punch for creating a tape specifically for use with the MPP. Figure 12-1 illustrates a part which has three holes to be measured. Table 12-1 lists the commands for measuring the holes as they would be entered through the MPP keypads. Following are the steps necessary to punch this program onto a paper tape.

a. Write out the entire program in the format in which it will be punched into the tape. In the instance of the table 12-1 command loop the E terminators would be replaced by typing the carriage return (abbreviated CR) and line feed (abbreviated LF) keys.

A portion of the table 12-1 program prepared for punching into a tape would appear as follows:

```
-1F12CRLFF12D2F15CRLFF12CRLFF12D3F15CRLFF7CRLF
XYF4CRLF34.12F51CRLF.005CRLF.005CRLF.005CRLF....etc.
```

b. Turn on the power to the Teletype and set the Teletype control switch in the LOCAL position.

c. Push the ON pushbutton on the tape punch control unit.

d. Press, and hold down for a few seconds, the HERE IS key on the keyboard. This will cause the punch to generate a length of blank "leader" tape.

e. Type all of the commands and comments written out in step a. The characters punched into the tape will also appear on the Teletype printer. If an incorrect character is typed, firmly press the B.SP (backspace) key on the punch control unit and then press the RUB OUT key on the keyboard. Doing this, in essence, erases the error and allows the operator to go on and type the correct character.

f. Once the tape has been punched, turn on the power to the MPP and ensure that the MM/INCH switch is set to correspond with the measurement units as they were punched into the tape.

g. Set the Teletype control knob to the ON position (on some machines the LINE position).

h. Set the tape reader control to the FREE position.

i. Place the "leader" holes at the beginning of the tape over the reader sprocket wheel.

j. Set the tape reader control to START.

k. Enter the F41E command via the MPP keypads to select the Teletype as the input device. When this command is executed, the MPP-2 immediately begins reading the program on the paper tape and the measurement procedure is started, as if the operator were executing any command loop via the MPP keypads or the Teletype keyboard.

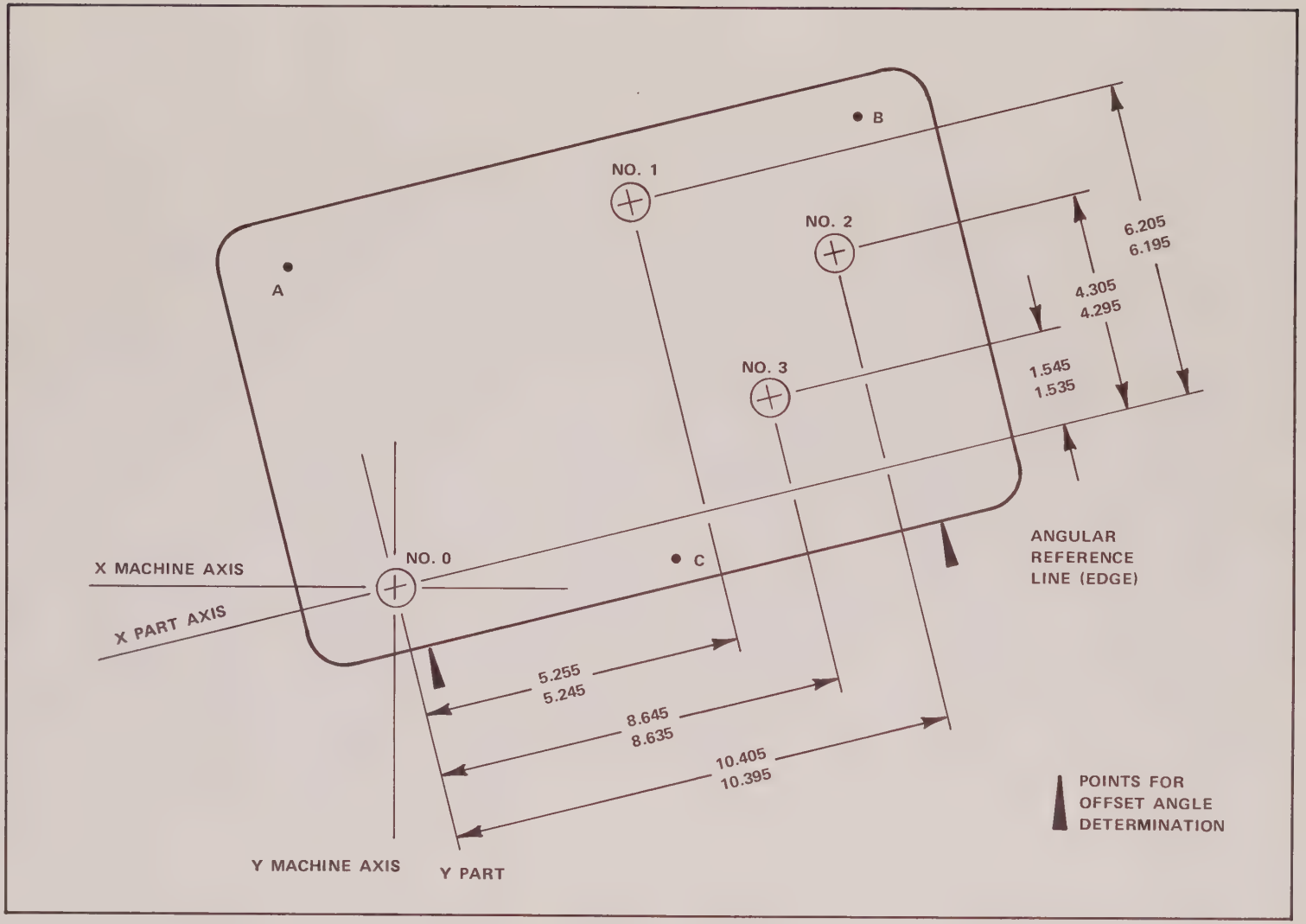


Figure 12-1. Illustration of the Part Measured Using Paper Tape Part Program

Table 12-1. Part Program for Workpiece Illustrated in Figure 12-1.

STEP 1: ALIGN PART

-F12E	Set the sequence number to -1.
F12D	Display the sequence number (-1).
2F15E	Wait for two points to be recorded (for offset angle computation).
FE	Compute offset angle.

STEP 2: SET REFERENCE DATUM

F12E	Increment sequence number (from -1 to Ø).
F12D	Display sequence number (Ø).
3F15E	Wait for three points to be recorded (for three-point centerfind).
F7E	Three-point centerfind for I.D.
XYF4E	Set reference datum for X and Y axes to the last recorded point.

STEP 3: ENTER TOLERANCE DATA

34.12F51E	Data Entry command stating that plus and minus tolerances for X and Y axes will be entered.
.005E	Plus tolerance for X axis.
.005E	Minus tolerance for X axis.
.005E	Plus tolerance for Y axis.
.005E	Minus tolerance for Y axis.

STEP 4: ENTER NOMINAL DATA FOR HOLE #1

2.12F51E	Data Entry command stating X and Y nominals will be entered.
5.25E	X-axis nominal.
6.2E	Y-axis nominal.

STEP 5: MEASURE HOLE #1

F12E	Increment sequence number (from Ø to 1).
F12D	Display sequence number (1).
3F15E	Wait for three points to be recorded (for three-point centerfind).
F7E	Three-point centerfind for hole #1.
2156.12F71E	Print nominal, actual, deviation and out-of-tolerance headings.
F61E	Print X and Y axis data for format specified in preceding (F71) command.

STEP 6. ENTER NOMINAL DATA FOR HOLE #2

F51E	Data Entry command utilizing default feature, i.e., prompts will be identical to those for the last command in which F51 was used when nominal data was entered for hole #1.
10.4E	X-axis nominal for hole #2.
4.3E	Y-axis nominal for hole #2.

Table 12-1. Part Program for Workpiece Illustrated in Figure 12-1 (cont.)

STEP 7. MEASURE HOLE #2

F12E	Increment sequence number (from 1 to 2).
F12D	Display sequence number (2).
3F15E	Wait for three points to be recorded (for three-point centerfind).
F7E	Three-point centerfind for hole #2.
F61E	Print X- and Y-axis data for format specified in preceding F61E command.

STEP 8. ENTER NOMINAL DATA FOR HOLE #3

F51E	Data Entry command utilizing default feature, i.e., prompts will be identical to those for the last command in which F51 was used.
8.64E	X-axis nominal for hole #3.
1.54E	Y-axis nominal for hole #3.

STEP 9. MEASURE HOLE #3

F12E	Increment sequence number (from 2 to 3).
F12D	Display sequence number (3).
3F15E	Wait for three points to be recorded (for three-point centerfind).
F7E	Three-point centerfind for hole #3.
F61E	Print X- and Y-axis data for format specified in preceding F61E command.

SECTION 13. SPECIFICATIONS, MAINTENANCE AND TROUBLESHOOTING

This section includes the information with which the operator should be familiar in order to maintain the MPP and to diagnose the source of any problems which may arise.

After the MPP has been mounted to the podium or in the vertical console and the cables from the Cordax machine have been plugged into the appropriate receptacles in the back of the chassis (as described in the Cordax machine instruction manual), the MPP is ready for operation. However, it is recommended that the preceding chapters on MPP operation and the following sections describing the back of chassis physical features and system specifications be read and understood before attempting to make any adjustments to the system.

13-1. PHYSICAL FEATURES OF THE BACK OF THE MPP CHASSIS

Physical features of the front of the MPP chassis are described in section 2. The physical features of the back of the chassis, as shown in figure 13-1 are as follows:

Power/Off circuit breaker not only functions as the power switch for the MPP but also automatically interrupts power in the event of line current overload.

Lamp Adjust potentiometer is used to set the common supply voltage for the exciter lamps in all the connected axis position transducer reading heads.

Lamp Test voltage jack is the test point for measuring the adjustable lamp supply voltage.

Z Fault Cable Receptacle is a three pin fitting for the Z fault cable used on Cordax Models 803, 805, and 807 only. This cable transmits an automatic locking singal to the Z-axis lock on the 800 series vertical arm measuring machines causing the Z-axis lock to be automatically activated when the vertical arm transducer indicates that the arm is traveling faster than a predetermined safe speed.

Power Cord is a three wire cord that should be plugged into a grounded three-wire receptacle. To determine if the MPP is properly grounded after installation, use a voltmeter to measure any voltage that might exist between the metal frame of the chassis and the external ground.

Axis Position Transducer Inputs. Up to four axis position transducers can be connected to the MPP via cables terminating with 15 pin D-connectors which plug into receptacles on the amplifier/check/divide circuit boards.

There is one such circuit board for each operative axis of the Cordax machine; figure 13-1 shows an MPP set-up for three axes, the X, the Y, and the Z. If a W axis were a part of this system, the circuit board with

receptacle for the W-axis cable would be immediately to the left of Z-axis cable receptacle shown in the figure.

Above the cable receptacles, the back edge of the amplifier/check/divide circuit boards are visible through slots in the chassis back. Mounted onto these boards, from top to bottom, are:

Count Reverse Switch: One of these switches is mounted at the top right side of each axis circuit board. They are used to reverse the sense of the plus and minus count relative to the direction of axis travel. The switches are located adjacent to exposed electrical conductors, and therefore the power cord must be disconnected from the power source before operating these switches.

Gain and Balance Adjustment Potentiometers: Four of these potentiometers are mounted to the right side of each axis circuit board just below the count reverse switch.

Amplifier Test Points: Five of these test points and one ground are located on the right side of each axis circuit board, just below the potentiometers.

Peripheral Device Cable Receptacle is located immediately to the right of the X-axis amplifier/check/divide circuit board on MPP's so equipped. This receptacle accepts the 25 pin D connector of the peripheral device (e.g., teletype) cable.

Omniprobe/Footswitch Cable Receptacle is located immediately below the peripheral device cable receptacle.

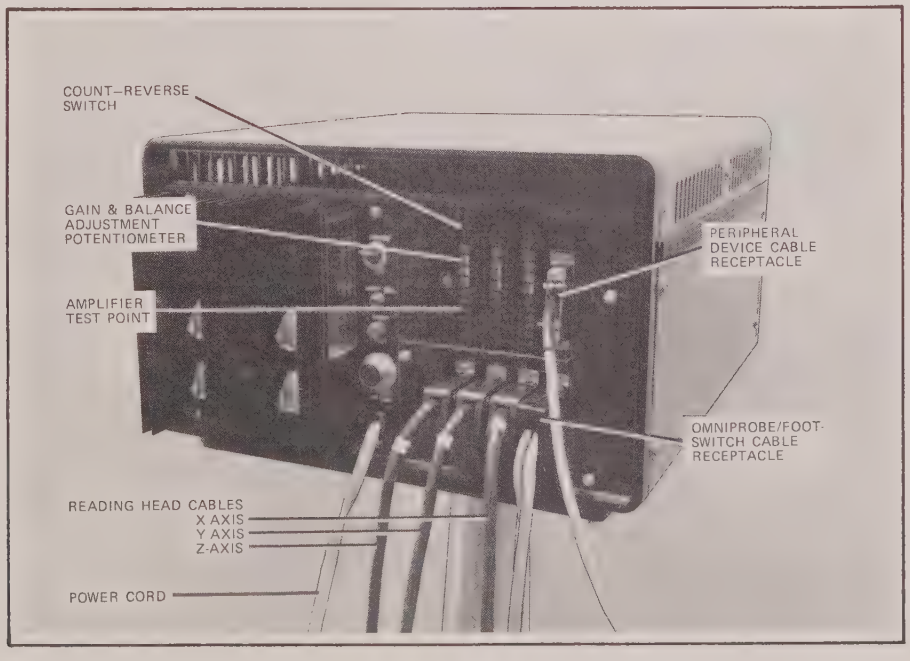


Figure 13-1. Physical Features of the Back of the MPP Chassis

13-2. MPP SPECIFICATIONS

Line Voltage Requirements

Standard: 95 to 125 VAC @ 60 Hz
Optional: 190 to 250 VAC @ 50 Hz

Measuring Range*:

Millimeter: ±99999.99 or ±9999.999
Inch: ±9999.999 or ±999.9999 (99.99999)
Degree: ±9999.999

Output: Depends on options slected

Operating Temperature:

Maximum 50^{o} C (122^{o} F)
Minimum 0^{o} C (32^{o} F)

Maximum Count Rate:

1016 mm (40 in.) per second

Chassis Dimensions:

Length: 395 mm (15.5 in.) (includes heat sink)
Width: 324 mm (12.8 in.)
Height: 190 mm (7.5 in.)

Weight:

10 kg (22 lbs)

Signal Input:

Reversible quadrature sine waves from Bendix moire fringe axis transducers or reversible quadrature square waves from rotary encoders.

Operator Input:

24-position keypad and/or optional external device.

13-3. TROUBLESHOOTING AND ADJUSTMENTS

The information contained in this section is provided to assist the maintenance technician in troubleshooting and adjusting the Cordax system. It is written from the viewpoint that the technician has a basic knowledge of circuitry, electronic test equipment, and electronic equipment repair. Any problems which are outside the scope of this section should be referred to the Customer Service Department of the Bendix Automation and Measurement Division or to the local Bendix Sales Office.

Following are descriptions and lists of steps for performing procedures to clean the Cordax machine gratings, to set the grating code switches and to install transducers. Table 13-1 provides troubleshooting hints which should be useful in isolating the cause of problems which may be encountered.

13-3.1 Cleaning the Gratings

There is one grating scale for each axis of the Cordax machine, and it is along these scales that the transducer reading head assemblies travel.

Cleaning the machine gratings is not regarded as a routine maintenance procedure and should not be performed unless considered necessary to remove foreign particles which are causing an erratic display and/or axes fault indications. Use the following procedure to clean the axis gratings:

CAUTION

Lighter fluid, which is recommended in this procedure, is flammable. Use according to container instructions.

Use extreme care to avoid scratching the grating. If the grating is damaged, it cannot be repaired and, therefore, must be replaced.

1. Remove the measuring machine covers, if necessary.

2. Moisten a cotton ball or a soft lint-free cloth with colorless, unscented lighter fluid. Squeeze out any excess fluid.

3. Lightly wipe the grating clean using a long stroke in one direction. Do not rub.

13-3.2 Setting the Grating Code Switches

The grating code switches are factory set to provide the proper divide factor in accordance with the grating scale used on the Cordax machine. These switches, located on the upper right component side of each amplifier/check/divide circuit board, are two-position rocker switches (see figure 13-2). Figure 13-3 shows the circuit board locations as viewed from the top with the chassis cover removed. The switch configurations for the various grating scales are shown in table 13-2. If the grating code switches are

Table 13-1. Troubleshooting Hints

Symptom	Suggestion
The POWER/OFF switch will not stay in the POWER position	Measure the AC line voltage at the receptacle with an AC voltmeter to determine whether it agrees with the voltage on the data tag on the rear of the Pre-Processor chassis. Refer to table 1-1 for tolerances. If the line voltage is within limits, call the Bendix Service Department.
No display lights	Ensure that the POWER/OFF switch/circuit breaker is in the POWER position. However, if the switch is not operating properly do not force it to stay in the POWER position. Check the AC power cord for a bad connection or for damage.
Display responds erratically or not at all when a machine axis is moved	Check the machine for mechanical problems such as dirty gratings, loose mechanical components, etc. Check axis transducer cables for damage or for loose connections. The following steps will identify whether the problem is in the Measurement Pre-Processor, the axis cable, or the transducer: (1) Exchange an axis cable at the rear of the chassis with one of the other cables. If the problem persists with the same axis display, the trouble is within the MPP. Call the Bendix Service Department. (2) If the trouble follows the exchanged cable, the problem is in either the cable or the transducer. Put the cables in the original positions at the chassis and then exchange the two cables at the transducer end. If the trouble appears in the original axis display, the problem is in the changed transducer, the transducer is defective. In either case, call the Bendix Service Department for assistance. If an axis fault light on the Preprocessor is lit, check the position transducer signal conditions as described in this section.
Axis display reads in error by some fixed percentage.	Check the setting of the Grating Code Switches on the amplifier/check/divide circuit board. An explanation of these settings is given in table 8-2.

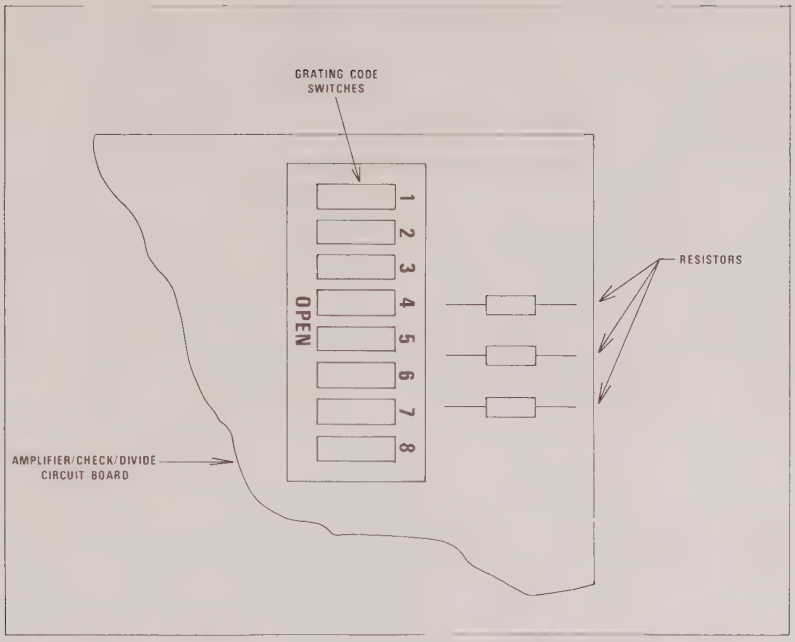


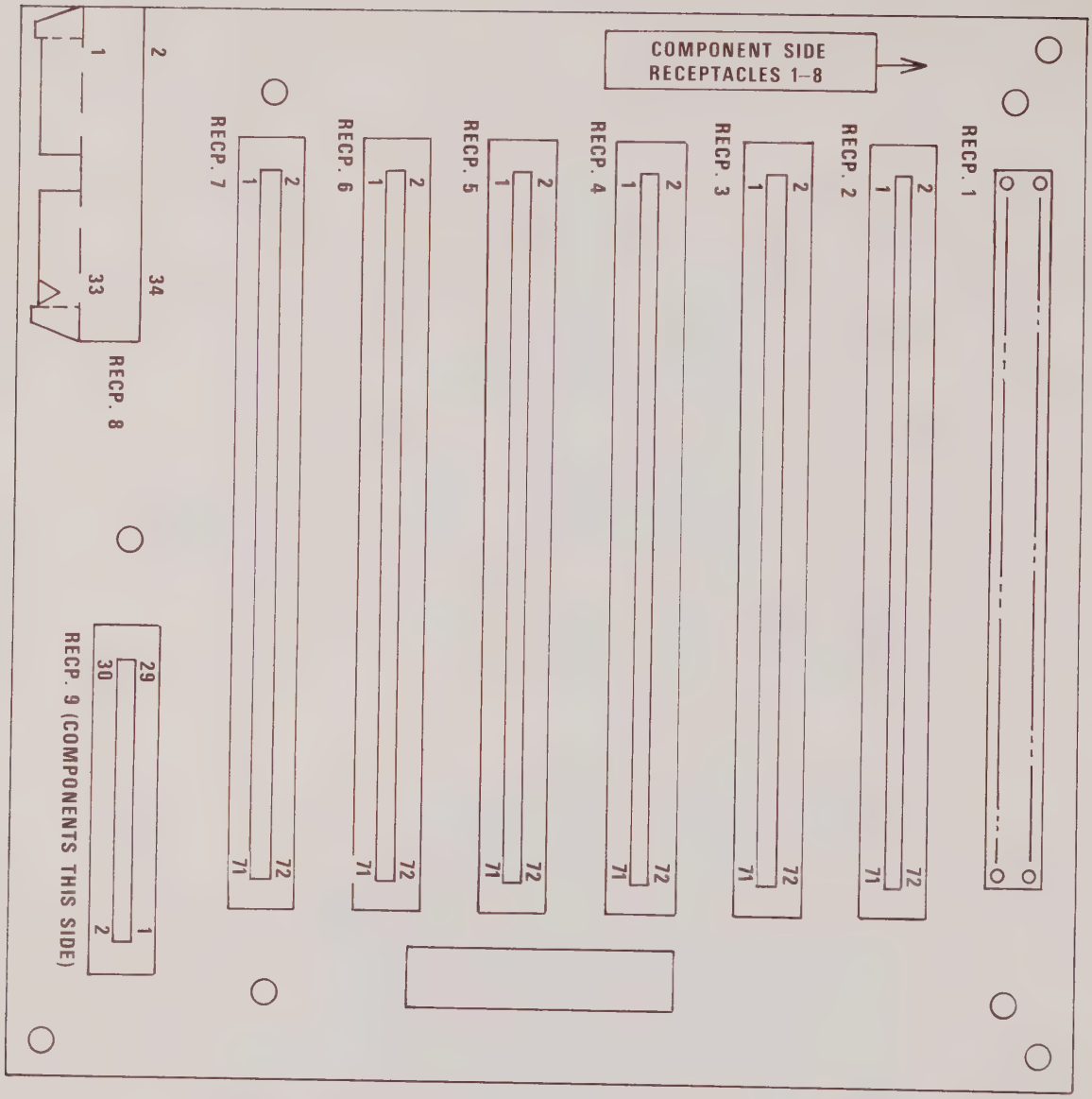
Figure 13-2. Grating Code Switch Component

Table 13-2. Grating Code Switch Selections

S1	S2	S3	Divide Factor	Grating Pitch	Measuring System
C	C	C	24	41 2/3 LPMM	Cordax Machines
O	C	C	24	41 2/3 LPMM	Cordax Spar Systems
C	O	C	4	25 LPMM	635-LPR Encoders
O	O	C	24	1,000 LPI	Cordax Machines
C	C	O	24	36,000 LPR	Rotary tables for Horizontal Arm (HA) Inspection Machines
O	C	O	24	15,000 LPR	
C	O	O	24	30,000 LPR	

C denotes closed
O denotes open

LPMM = lines per millimeter
LPI = lines per inch
LPR = lines per revolution



Receptacle 1:	Spare
Receptacle 2:	MPP Memory
Receptacle 3:	Control Terminal Interface, Footswitch and Omniprobe
Receptacle 4:	X axis
Receptacle 5:	Y axis
Receptacle 6:	Z axis
Receptacle 7:	W axis
Receptacle 8:	Display/Keypads
Receptacle 9:	Power Supply

Figure 13-3 Circuit Board Location Chart

improperly set (indicated by display errors of a fixed percentage) reset the switches in accordance with table 13-2 using the following procedure:

1. Turn off power and disconnect the MPP from the power source.

2. Remove the eight screws holding the top cover and lift it off the MPP chassis.

3. The code switch component is protected by a clear plastic cover. Remove the cover.

4. Use a blunt-ended instrument to reset the switches. Only switches 1 through 3 are used; switches 4 through 8 are not connected.

5. Replace the plastic switch cover.

6. Replace the top cover on the MPP chassis.

7. Reconnect the MPP at the power source and turn on the power.

13-3.3 Adjusting or Replacing the Reading Heads

The transducer (reading head) set-up procedure given in the following paragraphs must be used when installing a new or replacement reading head or when restoring reading head signals which are marginal or below acceptable levels. The set-up procedure consists of four steps: setting the air gap, setting the reading head skew angle, setting the gain and balance adjustments on the amplifier/check/divide circuit boards and checking the fault waveform.

The following equipment is necessary to perform this procedure:

- -Oscilloscope with the facility for displaying a circular lissajous pattern of 0.5 to 20 volts peak to peak with a one-to-one (1:1) ratio between the vertical and horizontal inputs. The input channels must have selectable AC and DC couplings.
- -A 7/64-inch hex wrench
- -A pot-driver for the amplifier/check/divide circuit board potentiometer
- -Plastic or paper shim stock 0.05 mm (0.002 in.) thick

1. Setting the air gap. The reading head air gap setting need only be adjusted when:

   a. The previous air gap setting is known to have been disturbed.

   b. A new or replacement reading head is being installed.

   c. Both the reading head skew adjustment and MPP amplifier adjustment have been attempted without obtaining adequate reading head signal amplitude (assuming the reading head exciter lamp voltage is properly set).

   d. In some rare cases, replacement of the reading head exciter lamp will necessitate a readjustment of the air gap.

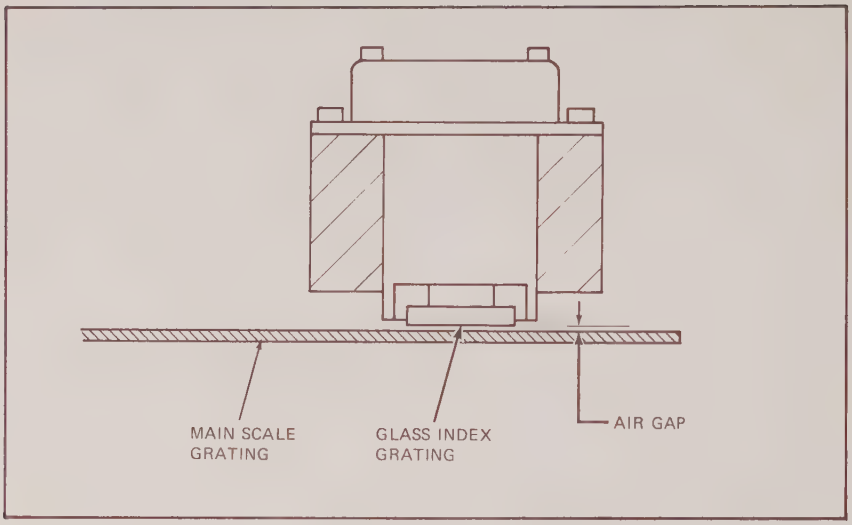


Figure 13-4. The Reading Head Air Gap

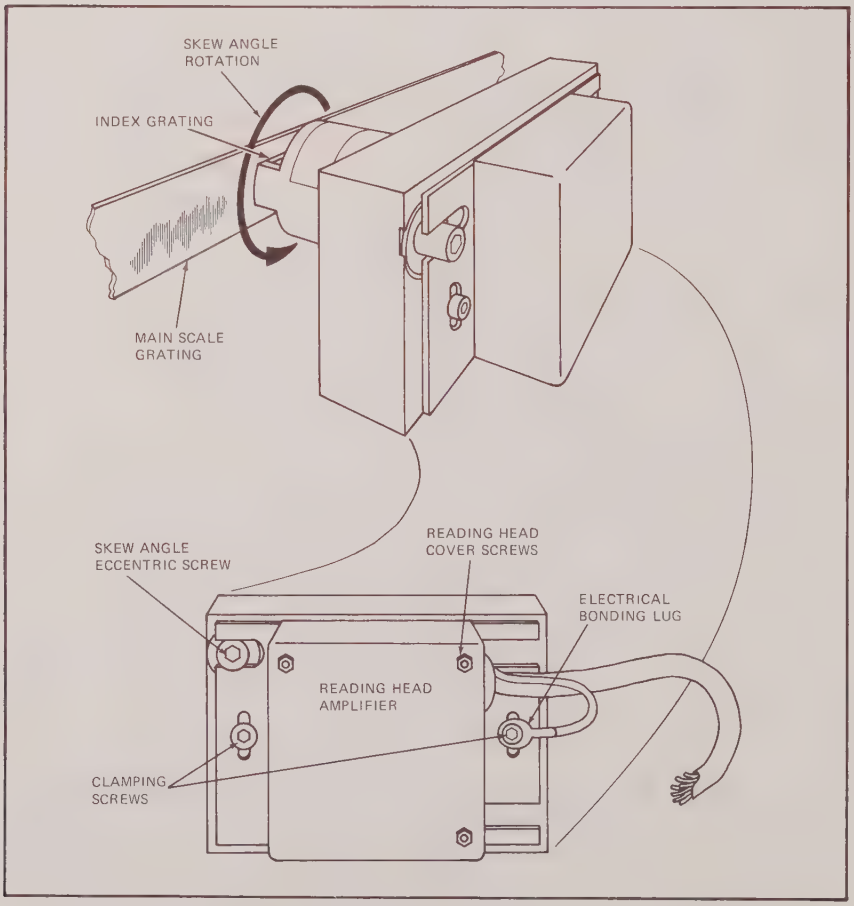


Figure 13-5. Reading Head and Scale Grating

To set the air gap:

a. Remove the covers from the Cordax measuring machine, if necessary, to obtain access to the reading heads.

b. Loosen the two hex head screws which hold the reading head mounting bracket (not the clamping screws on the reading head body). The mounting brackets have slotted holes under the hex-head screws which allow the bracket and reading head to be moved toward or away from the main scale grating for air gap adjustment.

c. Cut several soft paper or plastic shims (perferably three layers or more) to make up the thickness of the required air gap setting. The air gap shims should be approximately 12 mm (0.5 in.) wide by 125 mm (5 in.) long so they can be manipulated between the main scale grating and the reading head index grating. Do not use metal shim stock.

NOTE

A nominal air gap setting is marked on each reading head; however, the actual optimum setting might vary slightly under differing conditions.

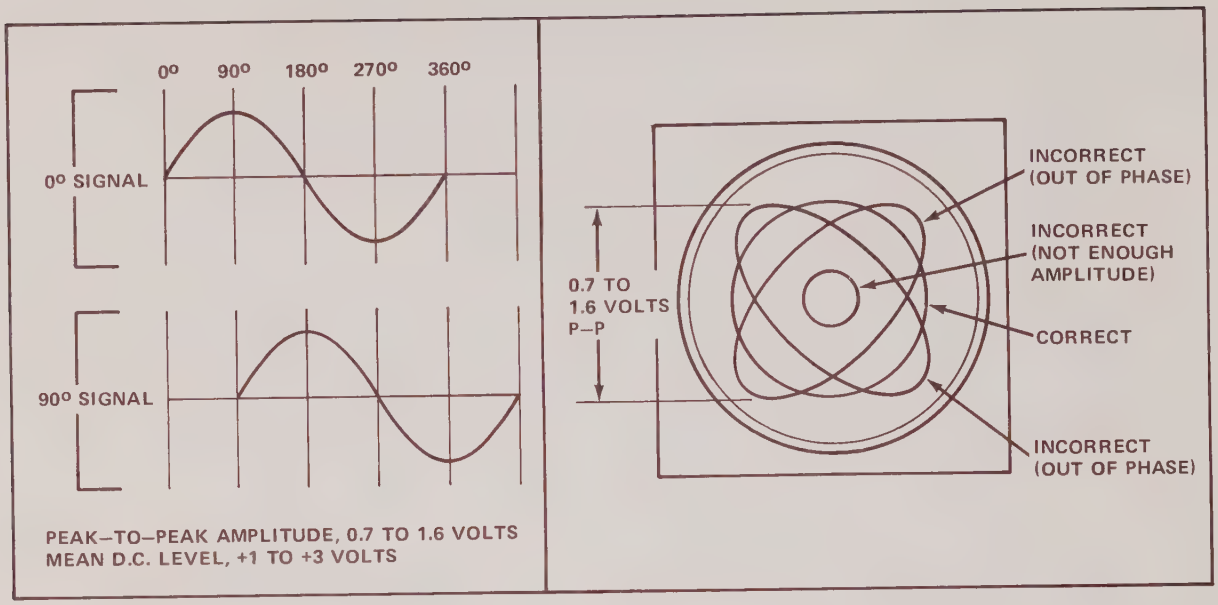
d. Place the ends of the gage shims between the index grating and the main scale gratings. Very gently, press the reading head toward the main scale grating. While moving the shims slightly to ensure that the force on the grating is not excessive, tighten the two hex head bracket-holding screws. Do not move the machine axis while the gage shims are in the air gap.

e. After the hex-head bracket screws have been re-tightened, ensure that the shims in the air gap are still loose enough to allow them to be pulled free (middle one first) without scratching the index grating. If they are not, loosen the hex screws and readjust them.

f. Move the reading head along its full range of travel, stopping occasionally to insert the gage shims to check that the gap is uniform.

g. The air gap setting is considered correct if an adequate reading head signal can be obtained after adjusting the skew angle and the amplifier pots.

2. Setting the Reading Head Skew Angle. The purpose of the skew adjustment is to establish the proper angle between the grid lines on the main scale grating and the similar lines on the reading head index grating. Make sure the reading head is positioned relative to the main scale grating as shown in figures 13-4 and 13-5. The adjustment is performed by physically rotating the reading head and its index grating with respect to the main scale grating while observing, on the oscilloscope the phase relationship and amplitude of the 0° IN and 90° IN reading head signals. The signals can be observed on the oscilloscope either directly as sine waves (see figure 13-6 (a)), or indirectly as a circular lissajous pattern (see figure 13-6 (b)). The lissajous pattern is preferred since it permits more accurate observation of the phase relationship.



(a) Conventional Display

(b) Lissajous Display

Figure 13-6. Reading Head Input Signal Waveforms

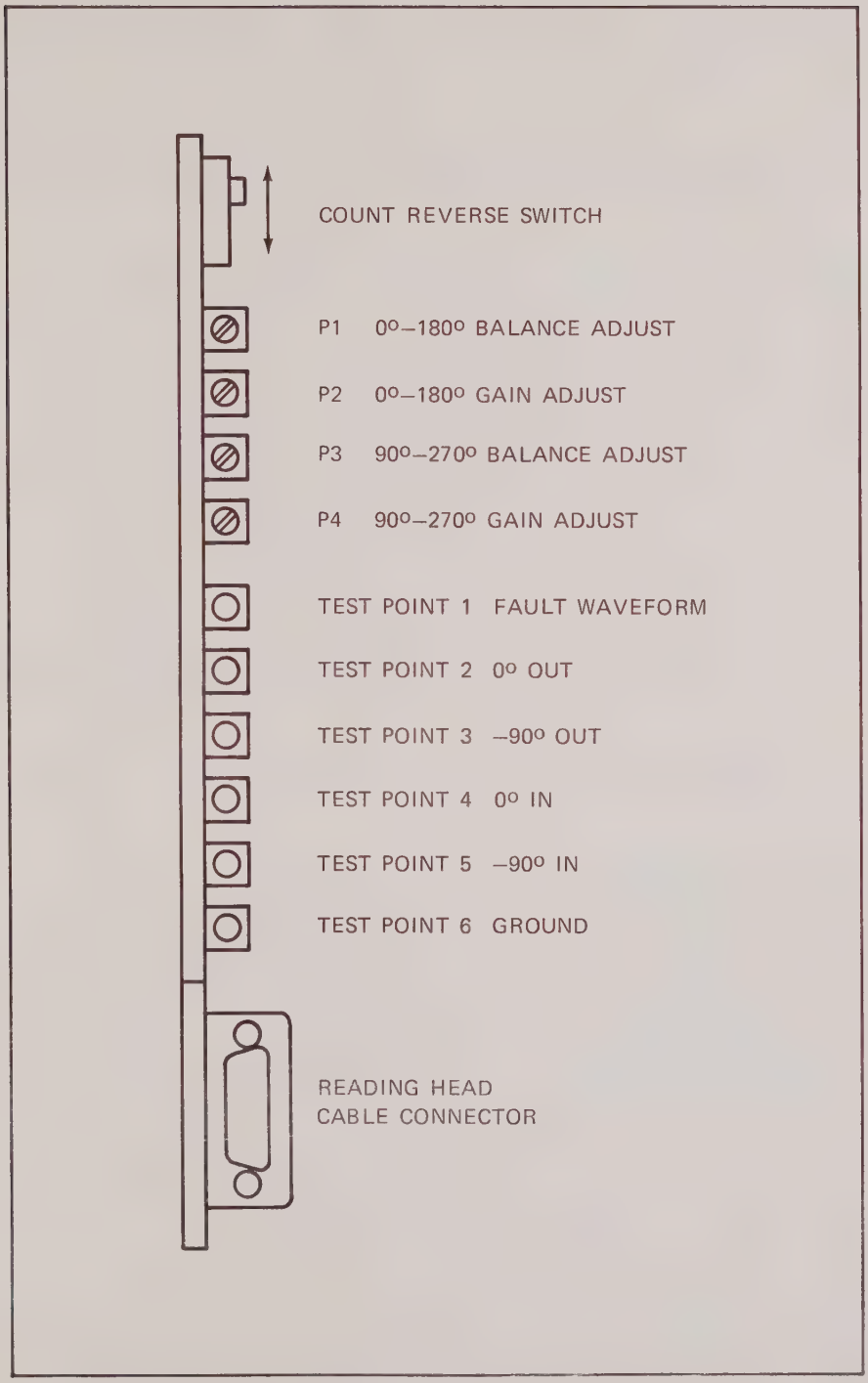

COUNT REVERSE SWITCH
P1 0°–180° BALANCE ADJUST
P2 0°–180° GAIN ADJUST
P3 90°–270° BALANCE ADJUST
P4 90°–270° GAIN ADJUST
TEST POINT 1 FAULT WAVEFORM
TEST POINT 2 0° OUT
TEST POINT 3 –90° OUT
TEST POINT 4 0° IN
TEST POINT 5 –90° IN
TEST POINT 6 GROUND
READING HEAD
CABLE CONNECTOR

Figure 13-7. The Amplifier/Check/Divide Circuit Board (÷24)

Before starting the skew adjustment procedure, ensure that the air gap is properly set and that the main scale grating is clean and free of any foreign material which would affect its reflectivity. Adjust the skew angle as follows:

a. Connect the oscilloscope ground to Test Point 6 on one of the amplifier/check/divide circuit boards (see figure 13-7) at the rear of the Pre-processor chassis. (All boards have the same ground test point.)

b. Select DC coupling on the oscilloscope and measure the reading head exciter lamp DC voltage at the LAMP TEST jack on the rear of the chassis (see figures 13-1 and 13-7). Turn the LAMP ADJ. pot (at the rear of the chassis) until the DC voltage reads 4.5 volts.

c. With the oscilloscope set for external horizontal input and with both signal probes temporarily grounded, position the oscilloscope dot vertically and horizontally to establish zero volts at the center of the screen.

d. Set the vertical and horizontal sensitivities to a value which will accommodate the signal amplitudes illustrated in figure 13-6. Select AC input coupling on both channels.

e. Connect the two signal probes to Test Points 4 (0° IN) and 5 (90° IN) on the amplifier/check/divide circuit board (see figure 13-7).

f. Loosen the two clamping screws (see figure 13-5) on the reading head until the reading head body can be moved snugly under the screws when the skew angle eccentric screw is turned.

g. While moving the machine axis very slowly back and forth along its travel, slowly turn the skew angle eccentric screw and observe the waveform on the oscilloscope. If the skew angle is too far out of adjustment, there will be no signal initially and the dot will remain stationary. As the eccentric screw is turned and the skew angle approaches the correct setting, the dot will begin to move either clockwise or counterclockwise (depending on the direction of axis travel) first in an elliptical path and then in a circle. The first waveform will normally be quite small. As the eccentric screw is turned further toward the correct setting, the small circle will become an ellipse again and then collapse. Continued adjustment of the eccentric in the same direction will result in a new, larger ellipse, then finally a larger circle as shown in figure 13-6 (b). Eventually the successive waveforms will become smaller if the adjustment is continued in the same direction and finally the dot will remain stationary.

h. The correct skew angle setting is the one which produces the largest and most perfect circle on the oscilloscope. After the best circle has been found, carefully re-tighten the reading head clamping screws. Recheck the signals to ensure that the setting did not move as the clamping screws were tightened.

3. Adjusting the Gain and Balance. The purpose of this procedure is to adjust the amplifier 0°-180° and 90°-270° output waveforms for the correct gain and balance. The test points and the adjustments are shown in figure 13-7.

a. Connect the oscilloscope ground to Test Point 6 on one of the amplifier/check/divide circuit boards. (The ground test point is the same on all boards.)

b. Select DC coupling on the oscilloscope channel and set the triggering to external and automatic.

c. With the oscilloscope signal probe grounded, center the trace vertically on the screen. This will be the zero volt DC reference.

d. Connect the oscilloscope signal probe to observe the 0° OUT waveform at Test Point 2 on the amplifier/check/divide circuit board. The desired waveform is a sine wave of approximately 18 volts peak-to peak amplitude which must be symmetrical (centered) vertically about zero volt DC (see figure 13-8).

e. If the sine wave is not symmetrical about the zero volt reference, adjust the 0°-180° Balance Adjustment, P1, on the amplifier/check/divide circuit board.

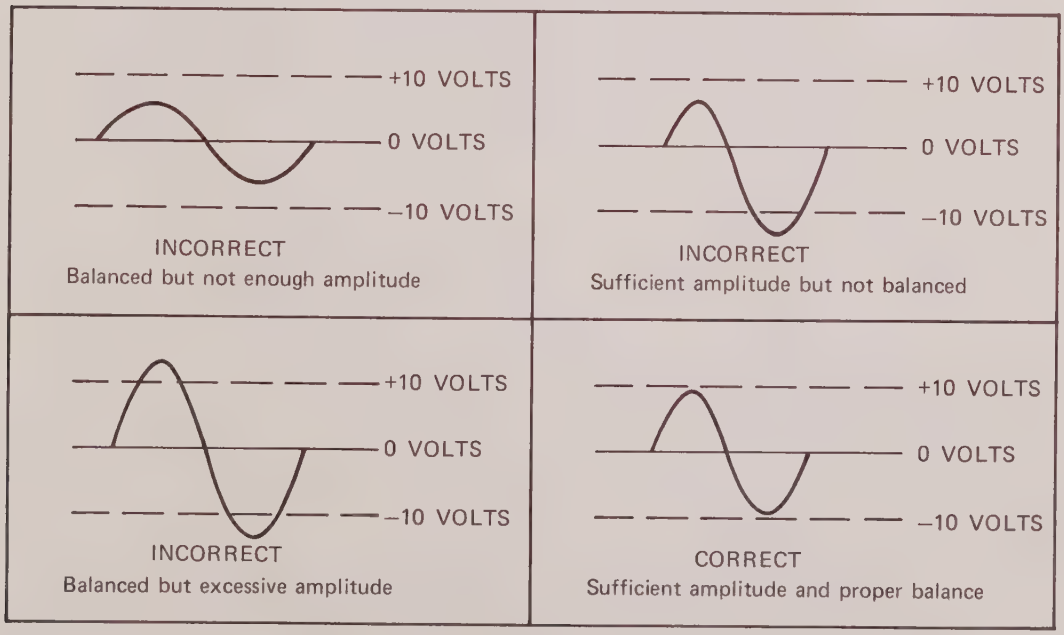


Figure 13-8. The Output Sine Wave

f. Set the peak-to-peak amplitude of the sine wave to approximately 18 volts by adjusting the 0° GAIN Pot, P2, on the amplifier/check/divide circuit board.

g. There is some interaction between the balance and gain adjustments. Therefore, after adjusting one, check and re-adjust the other, if necessary, until both are satisfactory as illustrated by the correct waveform in figure 13-8.

h. Move the oscilloscope signal probe to Test Point 3 to observe the 90° OUT waveform. Repeat steps b through g using, in this case, the 90°-270° BALANCE and GAIN Potentiometers (P3 and P4).

i. Move the machine axis along its full range of travel while observing the 0°-180° or the 90°-270° waveforms. Both waveforms should remain within ±2 volts peak-to-peak amplitude and within ±2 volts shift in average DC level.

4. Fault Waveform Check. The fault waveform is a full-wave rectified composite of the 0-, 90-, 180-, and 270-degree output signals and is monitored by the Pre-Processor fault check circuit. The fault waveform is an excellent indication of the condition of the transducer signals and should always be checked with an oscilloscope after the transducer setup procedure has been completed. The fault waveform should appear as in figure 13-9 (a). The fault monitoring circuit is designed to issue an input fault warning, as shown in figure 13-9 (b), when any point on the waveform dips below a DC level of 3.3 volts. Therefore, the transducer signals should be adjusted so that a 2-volt margin exists between the lowest point on the waveform and the FAULT THRESHOLD level. If this condition is not met, the cause may be improper adjustment of the air gap, skew angle, lamp voltage, or the gain and balance adjustments. Repeat the set up procedure if necessary to achieve the correct fault margin. Check the fault waveform, in accordance with the following:

a. Ground the signal probe at Test Point 6 and position the trace at the bottom of the screen for zero volt reference.

b. Select DC input coupling on the oscilloscope and connect the signal probe to Test Point 1 on the amplifier/check/divide circuit board.

c. While moving the machine axis, observe the location of the lowest point of the waveform.

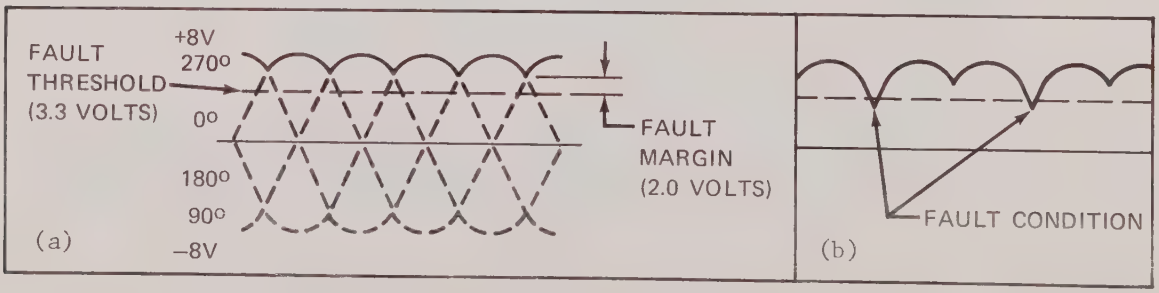


Figure 13-9. The Fault Circuit Waveform

SECTION 14. SERVICE AND SPARE PARTS

14-1. WARRANTY STATEMENT

The Bendix Measurement Pre-Processor has a highly advanced electronic system which requires special electronic test equipment for adjustments. For this reason repairs are made by Bendix Field Service Representatives who are skilled electronic technicians. Repairs by other than authorized Bendix personnel within the warranty period will automatically void the Bendix Warranty.

14-2. ORDERING SERVICE

To request service on the MPP, call the Order Service Department at 513-254-5377 or write to the following address:

The Bendix Corporation
Automation and Measurement Division
721 Springfield Street, Post Office Box 1127
Attn: Order Service Department
Dayton, Ohio 45401 U.S.A.

14-3. SPARE PARTS

The spare parts on the following pages are available for the MPP from the Order Service Department. Send orders for parts, clearly stating the part name and Bendix Part No. to:

The Bendix Corporation
Automation and Measurement Division
721 Springfield Street, Post Office Box 1127
Attn: Order Service Department
Dayton, Ohio 45401 U.S.A.

Bendix Part No.	Description
50081168	Processor/Memory (MPP) Board
50081169	Processor/Memory (MPP-1) Board
50081170	Processor/Memory (MPP-2) Board
50023292	Display/Keypad Board
50023278	Power Supply
50081123	Spare Parts Kit for MPP, MPP-1, and MPP-2 Stand Alone Units (.001 mm/.0001 in./.00004 in. Resolution) consisting of:
50023300	Omniprobe/Footswitch Control Board
50023281	Amplifier/Check/Divide (÷24) Board
50024407	Reading Head Lamp
50005089	2 Amp Fuse
50004978	5 Amp Fuse
50004033	10 Amp Fuse
50005034	1 Amp Fuse
50081125	Spare Parts Kit for MPP, MPP-1, and MPP-2 With Printer Or Teletype Interface (.001 mm/.0001 in./.00004 in. Resolution) consisting of:
50023290	Printer/Teletype/Footswitch/Omniprobe Control Board
50023281	Amplifier/Check/Divide (÷24) Board
50024407	Reading Head Lamp
50005089	2 Amp Fuse
50004978	5 Amp Fuse
50004033	10 Amp Fuse
50005034	1 Amp Fuse
50081126	Spare Parts Kit for MPP, MPP-1, and MPP-2 With Printer Or Teletype Interface (.01 mm/.001 in. Resolution) consisting of:
50023290	Printer/Teletype/Footswitch/Omniprobe Control Box
50023284	Amplifier/Check/Divide (÷4) Board
50005089	2 Amp Fuse
50004978	5 Amp Fuse
50004933	10 Amp Fuse
50005034	1 Amp Fuse

Bendix Part No.	Description
50081121	Spare Parts Kit for MPP With Computer (.01 mm/.001 in. Resolution) consisting of:
50023314	Computer/Footswitch/Omniprobe Control Board
50023319	Computer Interface Board
50023284	Amplifier/Check/Divide (÷4) Board
50005089	2 Amp Fuse
50004978	5 Amp Fuse
50004033	10 Amp Fuse
50005034	1 Amp Fuse
30001851	Lamp, Remote Control Box
50010110	Lamp, Start Panel
50081122	Spare Parts Kit for MPP With Computer (.001 mm/.0001 in./ .0004 in. Resolution) consisting of:
50023314	Computer/Footswitch/Omniprobe Control Board
50023319	Computer Interface Board
50023281	Amplifier/Check/Divide (÷24) Board
50024407	Reading Head Lamp
50005089	2 Amp Fuse
50004978	5 Amp Fuse
50004033	10 Amp Fuse
50005034	1 Amp Fuse
30001851	Lamp, Remote Control Box
50010110	Lamp, Start Panel
50081124	Spare Parts Kit for MPP, MPP-1, and MPP-2 Stand Alone Units (.01 mm/.001 in. Resolution) consisting of:
50023300	Omniprobe, Footswitch Control Board
50023284	Amplifier/Check/Divide (÷4) Board
50005089	2 Amp Fuse
50004978	5 Amp Fuse
50004033	10 Amp Fuse
50005034	1 Amp Fuse

APPENDICES

APPENDIX A
FUNCTION LIST

KEY: ( ) = AXIS LETTER X, Y, Z OR W; n = NUMERICAL VALUES
C = COLUMN; R = ROW

BASIC OPERATIONS, ALL MODELS		PAGE NO.
CLEAR (C)	CANCELS PARTIAL COMMAND (KEYPAD ENTRIES SINCE LAST E OR D DEPRESSION); CANCELS TEMPORARY DISPLAY; CANCELS ERROR DISPLAY	16
DISPLAY (D)	COMMAND TERMINATOR; MOVES DECIMAL POINT TO EXTENDED POSITION IF IN NORMAL MODE OR TO NORMAL IF IN EXTENDED MODE (INCH ONLY)	16
ENTER (E)	COMMAND TERMINATOR	16
FUNCTION (F)	USED WITH NUMBER TO SELECT COMMAND OPERATION	16
X RESET	RESETS DESIGNATED DISPLAY TO ZERO; CLEARS ALL FAULT-CAUTION CONDITIONS	16
Y RESET		16
Z RESET		16
W RESET		16
XnE	PRESETS SELECTED AXIS TO n VALUE AND STORES n VALUE IN MEMORY	40
YnE		40
ZnE		40
WnE		40
XE	PRESETS SELECTED AXES TO n VALUE PREVIOUSLY STORED IN MEMORY WITH XnE, YnE, ZnE or WnE	40
YE		40
ZE		40
WE		40

ALIGNMENT COMMANDS, ALL MODELS		
FE	COMPUTE OFFSET ANGLE	27
ØFE	CANCEL OFFSET ANGLE	28

ALIGNMENT COMMANDS, MODELS MPP-1 AND MPP-2 ONLY		
FD	DISPLAY OFFSET ANGLE	28
n°FE	SET OFFSET ANGLE	28
n°FlE	MODIFY OFFSET ANGLE USING DEGREES	29
()n()nFlE	MODIFY OFFSET ANGLE USING COORDINATES	29

ALIGNMENT COMMANDS, MODEL MPP-2 ONLY		PAGE NO.
-n OR nF23E	PLANE ROTATION	35
F23D	DISPLAY AUTO-LEVEL ANGLE	35
REFERENCE ESTABLISHING COMMANDS, MODELS MPP-1 AND MPP-2 ONLY		
F4E	SET REFERENCE FOR ALL AXES	42
()F4E	SET REFERENCE FOR AXIS	42
()nF4E	MOVE AXIS REFERENCE	42
F5E	SAVE ALL AXES REFERENCES	42
()()F5E	SAVE REFERENCE FOR () AXIS OR ()() AXES	42
F6E	RECALL ALL AXES REFERENCES	43
()()F6E	RECALL REFERENCE FOR () AXIS OR ()() AXES	43
MEASUREMENT COMMANDS, MODELS MPP-1 AND MPP-2 ONLY		
nF9E	SET PROBE DIAMETER TO n	47
F9D	DISPLAY PROBE DIAMETER	47
F7E	THREE-POINT CENTERFIND FOR I.D.	47
F8E	THREE-POINT CENTERFIND FOR O.D.	47
F7D	DISPLAY JUST MEASURED CENTERPOINT AND I.D.	47
F8D	DISPLAY JUST MEASURED CENTERPOINT AND O.D.	47
MEASUREMENT COMMANDS, MODEL MPP-2 ONLY		
nF24E	MULTI-POINT CENTERFIND FOR I.D.	48
nF25E	MULTI-POINT CENTERFIND FOR O.D.	48
F24E	SCANNING CENTERFIND METHOD FOR I.D.	48
F25E	SCANNING CENTERFIND METHOD FOR O.D.	48
nF26E	CENTERFIND FOR CIRCLE FORMED BY CIRCULAR FEATURES	50
DATA MANIPULATION COMMANDS, MODELS MPP-1 AND MPP-2 ONLY		
nF2E	SET SCALE FACTOR FOR ALL LINEAR AXES	43
()nF2E	SET SCALE FACTOR FOR AXIS	43

DATA MANIUPLATION COMMANDS, MODELS MPP-1 AND MPP-2 ONLY		PAGE NO.
F2D	DISPLAY SCALE FACTOR	44
F10E	CONVERT LINEAR TO POLAR COORDINATE DISPLAY	52
F11E	CONVERT POLAR TO LINEAR COORDINATE DISPLAY	52
F16E	CONVERT POLAR NOMINAL TO LINEAR NOMINAL	59
F17E	CONVERT LINEAR NOMINAL TO POLAR NOMINAL	59
F20E	RIGID PROBE REORIENTATION	37
DATA MANIPULATION COMMANDS, MODEL MPP-2 ONLY		
F27E	OMNIPROBE REORIENTATION	38
AUXILIARY COMMANDS, MODELS MPP-1 AND MPP-2 ONLY		
()()F3E	SELECT ACTIVE PLANE	35, 43
nF13E	SET TEMPORARY DISPLAY INTERVAL TO n SECONDS	61
F13D	DISPLAY TEMPORARY DISPLAY INTERVAL	61
nF18D	DISPLAY ONE OF SIX LAST RECORDED POINTS (n=1,2,3,4,5,6)	62
F18D	DISPLAY LAST RECORDED POINT	62
F19D	DELETE LAST RECORDED POINT	62
F21E	DISABLE FOOTSWITCH	62
F22E	ENABLE FOOTSWITCH	63
DATA ENTRY/DISPLAY COMMANDS, MODEL MPP-1 AND MPP-2 ONLY (SEE TABLE 10-1 FOR C.R DATA)		
C.RF50E	ENTER NOMINAL AND/OR TOLERANCE VIA MPP KEYPADS	54
C.RF60E	DISPLAY DATA ON MPP	57
DATA ENTRY/DISPLAY COMMANDS, MODEL MPP-2 ONLY		
C.RF51D	ENTER NOMINAL AND/OR TOLERANCE VIA CONSOLE DEVICE WITH ECHO ACTIVE	66
C.RF51E	ENTER NOMINAL AND/OR TOLERANCE VIA CONSOLE DEVICE WITH ECHO INACTIVE	66
C.RF61E	PRINT DATA ON CONSOLE DEVICE	67
C.RF71E	PRINT COLUMN HEADINGS ON CONSOLE DEVICE	67

PROGRAMMING COMMANDS, MODELS MPP-1 AND MPP-2 ONLY		PAGE NO.
nF14E	EXECUTE COMMAND LOOP n TIMES	63
F14E	EXECUTE COMMAND LOOP UNTIL HALTED	63
X	EXIT COMMAND LOOP	63
nF14D	RESTART COMMAND LOOP AND EXECUTE n TIMES	64
F14D	RESTART COMMAND LOOP AND EXECUTE UNTIL HALTED	64
±F12E	SET SEQUENCE NUMBER	68
F12E	ADD 1 TO SEQUENCE NUMBER	68
F12D	DISPLAY SEQUENCE NUMBER	68
nF15E	WAIT FOR n POINTS TO BE MEASURED (n=1,2,3,)	62
F15E	WAIT FOR 1 POINT TO BE MEASURED	62
PROGRAMMING COMMANDS, MODEL MPP-2 ONLY		
F41D	TRANSFER I/O CONTROL TO CONSOLE DEVICE WITH ECHO ACTIVE	65
F41E	TRANSFER I/O CONTROL TO CONSOLE DEVICE WITH ECHO INACTIVE	65
F40E	RETURN I/O CONTROL FROM CONSOLE DEVICE	65

APPENDIX B
ERROR MESSAGES

When the MPP detects an error, other than a hardware fault, it will show an error message on the X-axis row of the display in the following format:

ERROR ##

In this case, ## stands for the number of the error message as given in table B-1. The errors are divided into two types, display overflow (errors 01-05) and command data errors (all other error numbers).

The display overflow errors indicate that the number the MPP is trying to display is larger than it can handle under the given circumstances. Such overflow errors may be caused, among other things, by moving the probe out of the displayable range, presetting an axis to a value beyond the displayable range, or resetting the MM/INCH switch where the equivalent value in the new unit is too large to be displayed. Recovery from a display overflow error basically entails analyzing the cause and remedying it by, for example, moving the probe back into the displayable range, presetting an axis a second time to a displayable number, or returning the MM/INCH switch to the original position. Once the corrective action has been taken, the CLEAR keypad should be pressed and this will cause the display to return to normal probe tracking.

The command data errors result from incorrectly entering data as part of a command or entering an inappropriate command for the task at hand. Recovery from this type of error is accomplished by pressing the CLEAR keypad and correctly reentering the command.